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Fifty Years

WHAT is the outstanding development of the last fifty years? Politically, of course, the World War is predominant with its appalling loss of life, its remaking of maps, its overturning of dynasties, its disastrous dislocation of trade and industry. But, disturbing as the World War has been, its permanent imprint on the life of our times, and those ahead, is insignificant compared to the effects of man's adaptation of the machine to his needs.

SOME who read this will find it easy to recall the days of fifty years ago. They, perhaps, can decide which of the applications of machinery is the most important—whether our present means of transportation by rail, by road or through the air contribute more to our convenience and efficiency than our means of communication, with wires or without.

They can grasp by contrast, where the next generation cannot, the significance of transportation facilities so speedy that it is no longer necessary for converters of raw materials to lay in huge stocks far ahead with the attendant speculative risk; what it means to the clerk and to the mechanic to be able to work in a big industrial center and live in the country where their children have a chance to develop normally.

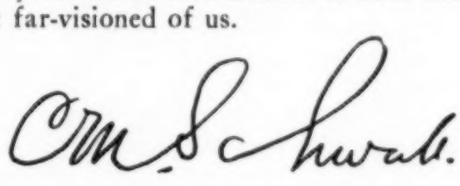
They are in a better position to realize the boon of light at the pressing of a button, of heat at the turn of a valve, of hot or cold water at the opening of a faucet.

They can estimate the extent to which drudgery has been relieved—in the home by washing, ironing and cleaning machines; on the farm by the tractor, the various agricultural machines and the individual lighting and pumping plants; in the shop by electrically controlled production machines and by conveyors, cranes, elevators and trucks.

They can begin to see results from scientific research and sane standardization, to get an inkling of the dazzling possibilities in the future when these two activities get the support and the recognition they deserve.

BUT all these things are material; they add to our comfort, they enhance our enjoyment of life, but they are not so directly connected with intellectual growth, with spiritual advancement. That way lies our road for the next fifty years.

Our material prosperity and our rapidly increasing productive capacity have shortened our working day and bid fair also to shorten our working week. Some few are convinced that that day is already at hand. In any event the leisure provided by the shorter day, and the shorter week, if it comes, must be devoted, in part at least, to spiritual and intellectual development. Otherwise, our civilization must surely follow the course of other material civilizations and perish. If we devote our free time to the attainment of moral and intellectual prosperity the next half-century will witness a standard of living beyond the wildest dreams of even the most far-visioned of us.



President
American Society of Mechanical Engineers

The Automobile Industry and Machine Tools

By C. F. KETTERING
Vice-President and Director
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THE broad statement that the development of machinery has gone hand in hand with the development of the motor car would be a truthful one, and I doubt if anyone would undertake to dispute it. But such a statement doesn't mean very much unless it is accompanied by concrete examples of how the two have been dependent upon each other.

The modern automobile, responding to the slightest whim of the average driver who has not the least knowledge of its mechanism, is seldom looked upon as a mass of intricate machinery itself. Yet it is the product of the largest group of expert technical minds that has ever been concentrated on a single subject.

In order to show the relation of machinery to the present-day motor car, a simple analysis of the important factors which had a part in the creation of the motor car may not be out of place. There have been three types of materials that have made possible these developments: First, oil; second, rubber; third, metals —and, in particular, alloy steels.

The influence of machinery in the development of each one of these three factors, of course, is outside of the range of this discussion, but their mention will at once give the reader a picture of the vital way in which machine development has affected the motor car in lines that are practically outside of the industry itself.

In referring to alloy steels, perhaps the development of the cutting materials has been of most importance, for it has been through the improvement in cutting materials that the decrease in the finishing time has been brought about. We can still remember when it took an hour and fifteen minutes to machine a flywheel. With the introduction of new cutting steels this time was reduced to thirteen minutes, at which point the machine itself would not withstand the strain. It was therefore necessary to redevelop and redesign the entire method of machining parts. I have not the latest data on the time required to produce a flywheel, but I presume it has been reduced considerably below thirteen minutes.

AS THE increased rate of machining parts came into practice, the necessity of moving those parts from operation to operation in our plants became more important and the automatic conveyor came in as a part of the production system used in making the automobile. The development of the conveyor, both automatic and manually controlled, has played an important part in eliminating much manual labor of a very laborious kind and in increasing production by decreasing both idle machine time and the frequent lifting of fairly heavy castings by the operator. A continuous flow of material to a machine not only prevents delay due to its nondelivery by trucks or other methods, but keeps the operator on his toes to prevent the man on the previous operation from piling up work. These various effects have all helped to reduce machining costs to their present low level.

As people began to understand the effect of automatic feeding devices on finishing rates, and operations became more perfectly timed, the necessity for abnormal stock rooms was eliminated; consequently, the inventory of plants could be reduced. Today, instead of treating a factory as being made up of a number of special machine tools, the whole unit can be considered as one tool which takes the raw material in at one end and delivers the finished product at the other end. We know of a motor plant in which the rough castings come in at one end and four hours later are finished motors at the other.

ALONG with this increase in quantity production there has come the idea held by a great many people that an article made in this fashion is not so good as the hand-made. However, those of us who have been in research and development work, where we have at our command the best mechanics and understand the art of the hand-made article, never expect that the experimental hand-made models will represent as high-grade mechanism as will be turned out in production by highly specialized machine tools. And we always expect to find greater precision and durability in the machine-made articles than in the hand-made ones.

And this brings out another very important point in connection with the value of highly specialized machinery. America excels in this respect. The number of "man hours" per ton of materials is the smallest of any country in the world, and with, perhaps, a grade of workmanship that is as high as, if not higher than, that of any other country in the world. In one of the European countries which produces a considerable number of automobiles, the number of "man hours" was ten times as high as it was in our American factories. If we will translate this into terms of wages and purchasing power, it is just another way of saying the American workman can produce an automobile in one-tenth the time required by the European neighbor. The machine tool, in reducing the man hours in relation to ton of finished material, has increased the value of these "man hours" and in consequence wages have gone up. And as wages have gone up, purchasing power has increased. The manufacturer has been enabled to sell more goods, and at a lower price.

In industry in general it can be shown by government statistics that each additional horsepower added by industry for its workers, through improved machinery,

during the ten years 1913 to 1923, resulted in an increased output by each worker of products valued at $1,310. And further, from 1914 to 1923, this country's man power increased 24.9 per cent. In the same period horsepower increased 47.6 per cent and production increased 58.8 per cent. This increase in production of both man power and horsepower was, of course, particularly marked in the automotive industry, which has enjoyed a greater proportionate increase in growth than any industry in any like period of time. And this growth can be largely attributed to the forward-looking attitude of the automotive industry in adopting highly specialized and costly machines to do the work of men.

Today we have more material assets per individual than any other country in the world. Many specific instances could be given as to how specialized machinery has reduced costs of production, but everyone who reads the *American Machinist* is so conversant with things of this kind that it is hardly worth mentioning them.

The writer has had many experiences in which factory output has been increased five, ten, fifteen or more times, by the development of special machine tools. The machine tool carries with it another very important factor: Where it has been impossible to get trained mechanics to do an exacting kind of work, the machine-tool designer has been obliged to design a machine that will produce better work than a trained operator can produce. This has in turn made it unnecessary for the operator to be specially skilled in any particular line. It has therefore opened greater possibilities for more unskilled people to procure employment and has greatly reduced the period of apprenticeship. A good, bright mechanic can today operate almost any kind of machinery. We have, of course, brought in and developed specialists so far as setting up the machinery is concerned. But knowing that the tools are properly arranged and the maintenance of the machinery is taken away from the operator, the rest is almost automatic.

The method of gaging finished work has also been an important factor that has gone hand in hand with the development of machine tools. The Go and No-Go gage, with its master control system, has made possible the production of more accurate articles at lower costs. In the gaging process we have eliminated the necessity for the final inspection and testing which used to be necessary.

RECENTLY a noted French engineer in going through a large motor plant made the remark, "I am surprised at your American factories. From what I had read I thought that the rate at which you put material through your factories would require a tremendous activity on the part of the operators and that these operators would be worked under such conditions and pressure that they could not long endure. I am quite surprised I didn't see anybody in a hurry, and yet there are thousands of tons of material passing through this factory and the degree of workmanship is as good as in any of our plants." This is another way of showing the relationship of the machine-tool idea to the organization of men by removing from the men the necessity of great hurry and unnecessary exertion. Machinery replaces both the manual labor and the necessity for speeds that fatigue both body and brain.

Transportation and the development of machine tools are the two big things that have made large output with minimum inventory. Instances have been pointed out where inventory turnovers have been increased from eight times per year to twenty-four times per year, and inter-factory conveyor systems have resulted in increasing turnover several times more. And there are still many opportunities along that line.

The individual unit of machinery in our plants has increased in size. This increase has been absolutely essential because of the demand for higher accuracy. The more accuracy required in the product, the bigger the machine must be. For mass, assuming that the metal is properly distributed, adds to rigidity and tends to prevent errors due to even very slight vibration. Consequently, we have seen in the automotive industry an increasing size of individual unit, which has made possible two things—longer operative life of the machine and more accurate finished product.

WE OF the automotive industry feel that, speaking collectively, we have led the way for all industry in the utilization as well as the development of automatic machinery. We were forced into this position, to be sure, but that does not alter the fact. There weren't enough mechanics in the country to meet our production requirements, so we had to devise machinery to meet the emergency. Then, as I have said, the economic factor forced us to improve upon the productive machinery in every conceivable manner, never hesitating to scrap even a comparatively new and expensive machine when a still newer one was developed that would speed up production, cut overhead, save human effort, give greater safety to the worker or improve the product. The automotive industry has provided a greater opportunity for the working out of highly productive machine tools than has ever been possible before.

When multiple machines first came into use there was a great deal of discussion as to their practicability. It was claimed that if one operation of the machine broke down it threw the equivalent of this whole machine out of commission. That was true at the beginning, as of any development, but the system has been worked out today so that a whole factory runs with practically no slack between the operations. As we continue the development of machine tools and their possibilities, we shall further increase the value of the "man hour."

The great progress of civilization has been the production at low cost of useful materials owned by the individual. The lower the cost of production, the higher the rate of wages, the more each individual owns. And while there is a great deal of discussion pro and con as to whether we are not developing a "machine age" in this country, I think that can best be answered by saying that no other country in the world enjoys so much leisure, such high real wages, possesses so many material things and has so many privileges as our own. I am sure that nobody need fear that future developments along this line will result in anything but constructive good. There is no limit as to what the individual may want, and no limit to what he can have so long as he contributes his own time and brain in producing these things and earning the money to pay for them. And in doing this, man is learning to harness machines to do things beyond the realm of possibility of "man power."

What Machinery Has Done for the Farmer

By WILLIAM M. JARDINE
Secretary of Agriculture

IT HAS been said that the standard of living of a people engaged in any industry may be accurately gaged by the quantity of labor-saving machinery utilized per worker in that industry. In perhaps no other industry is this more true than in that of agriculture. In certain European nations from one-fifth to one-tenth as much machinery and power is utilized per farm worker as here in the United States and the volume of crop production per worker in those countries is shown to be in almost exactly like proportion as compared with the average for this country. An even more striking example is that of China. In that country much of the work of crop production is still performed by human labor with the aid of only the crudest of hand tools. As a result of their methods, the productive effort of the Chinese coolie has a value of only a few cents per day.

Similar examples may be found by comparing different agricultural regions in the United States. In some regions at least ten times the quantity of machinery is utilized per farm worker compared with other regions and the volume of production per worker is usually greatest where the largest quantity of machinery is used.

For a considerable period of time the proportion of agricultural workers to those otherwise profitably engaged in this country has been rapidly lessening. In 1820 almost 90 per cent of the population in the United States lived on farms. In 1910 those engaged in agriculture were only about thirty per cent of those profitably engaged and yet this thirty per cent not only furnished food for themselves but also for the other seventy per cent, and there was a considerable exportable surplus of food products in addition.

WITH the advent of the war the demand for food tended to stimulate agricultural production. The availability of large machine units and motor power aided materially in obtaining the increase in food production per farm worker that took place. We should not decry too seriously the movement of part of our farm workers into other occupations at this time. This movement is needed to counterbalance the increases in efficiency which are constantly taking place.

The individual farmer knows that in so far as he, personally, is concerned the more he can produce the more will be his profits so long as there is not too serious a break in prices. As a matter of fact, many of our more progressive farmers are utilizing exactly this method to obtain a fair net income under existing conditions. Appreciating that total profits are solely dependent upon the price received per unit less the cost of production, multiplied by the total volume they have to sell, they have reduced their unit costs of production wherever possible, and have at the same time increased their output, often through the use of larger or faster machine units. Either of these last two factors is directly under the control of the individual farmer while the first factor, that of the selling price, is a difficult item to control.

THE utilization of labor-saving machinery on farms in this country had its inception about the middle of the last century. Prior to this period there were some improvements in the few crude tools used but practically all of these were made in the local blacksmith shops and their use continued to be limited. About 1850, however, great improvements were made in a number of machines and soon after this manufacturing on a relatively large scale was started.

Among the more important labor-saving farm machines that were first introduced were the mower and the self-binder. These were followed shortly by the improvement of the corn planter and the introduction of riding plows. The development of the steam traction engine aided materially in the use of larger and more efficient threshing machinery. The development and improvement of the gas tractor during the past quarter of a century has aided materially in making possible the utilization of larger and more efficient machine units. On the Pacific Coast the development of the combined harvester-thresher gave the wheat farmer one of the greatest labor-saving farm implements that has ever been produced. Its more recent introduction to the Great Plains area is proving the salvation of the farmer in the face of the prevailing low price of wheat.

There have been great improvements in farm machinery in the last three-quarters of a century, and American farmers use more machinery than those in most other countries, but there is further room for improvement. Mechanical equipment is utilized to replace human labor in but little over one-half of the work now done on American farms. Mechanical equipment is available for a considerable part of the work that is still done by hand, but for various reasons is not now employed. In some areas wages have been so low it was more economical to hire human labor than to use available machinery; in other cases machinery has not been developed to do the work economically where there is only a small amount to be done, or the proper kind of power and the proper means of applying it were not available. New types of machinery will undoubtedly be developed from time to time and the use of larger machine units will undoubtedly increase as the methods of power application are improved upon.

Electricity and the Mechanical Industries

By GERARD SWOPE
President, National Electrical Manufacturers' Association

BETWEEN the electrical and mechanical industries of our day there is a strong bond of mutual service and close interdependence. Neither, without the other, could have approached its present commanding position. Electricity, lacking the machine to turn its energy into useful work, would find its scope sadly limited, while the machine, if required to depend solely on other forms of energy for its driving force, would not possess the versatility that characterizes it now.

Electricity, grown from a laboratory experiment to its present vast commercial importance within the short period of fifty years, now supplies to the modern shops readily controllable power, heat, light, communication and transportation. At the same time it has greatly influenced the evolution of shop practice itself. For as the units by which power is generated or applied have grown from small beginnings to their present ponderous proportions, severe demands have been made of the equipment used to produce them in the shop.

As applied to the driving of machine tools, textile machines, printing presses and every other kind of machinery used in production, electricity has had a profound effect on machine design. The modern method of building the one or more driving motors into the machine conserves space, improves appearance and increases the comfort of the workman by increasing safety, improving the light and reducing the dust content of the air in the shop by doing away with belts and shafting. Not the least of the advantages is the flexibility secured in the modern shop equipped with individual motor driven tools. Rearrangement to meet new demands brought about by sudden market changes is comparatively simple and very rapid. And then electricity has also done much to facilitate production and repair work by means of the portable drill and other light portable tools that are limited in their portability only by the length of the wires attached to them.

FROM the point of view of the equipment builder the electrical manufacturing industry has also been important, in that it provides a market second only to the automotive industry. With the rapid development of the plants manufacturing electric refrigerators, washing machines and other domestic electric labor saving appliances the time may not be far distant when the electrical industry will take first place as a market for machine tools.

In some respects the electrical industry has been singularly fortunate in comparison with older industries and this may account in part for the spectacular rapidity of its growth. It has not been hampered by tradition. Getting its start at about the same time that engineering education was beginning to find itself, and when science was coming into its own, it escaped in large measure the rule-of-thumb methods that have held back some industries. Its very novelty attracted the pioneers in industrial thought and development, the men who were impatient with conservatism, who sought new things, and in the seeking were willing to take long chances. To the everlasting credit of these pioneers must be placed their faith in research, both in pure and applied science.

Beyond all else, of course, it has been the service which electricity has rendered to humanity that counts for most in the world; and in every field to which electricity has been applied this is conspicuous. It has developed communication until today all the peoples of the world have become one community, and we are sending our messages without wire, by speech, writing and pictures and even experimenting with "television."

LIKEWISE, in the field of transportation we have come, in fifty years, from wood burning steam locomotives to powerful electrical tractors, to multiple-unit suburban trains, to the electric street railway and the high speed interurban. Candles and oil lamps have given way to the metal filament incandescent lamp, which, at the turn of a switch, furnishes almost the equivalent of daylight. And in the home we cook and launder and clean with electricity and keep warm or cool with its aid.

But probably the greatest contribution that electricity has made to the well-being of mankind brings us back into the shop again. For in the last quarter century we have seen the use of mechanical power increase until today there is actually an average of four and a quarter horsepower behind the elbow of every worker in the factories of America. Meanwhile the use of electric power in industry has increased fifteen-fold. In 1899, electric motors constituted less than five per cent of the installed horsepower; in 1925, three-fourths was electrical. This means no less than that the modern workman equipped with power and machinery can produce three times as much as a similar worker of twenty-five years ago and with far less burden on his strength and less drain upon his health and happiness. And when we say that the modern factory hand produces more we mean that he is creating just that much increased wealth for men and women to enjoy, himself among them. The present unparalleled prosperity of the American people and the comforts we enjoy are in large part due to this fact. Here, I think, is electricity's greatest service, a service that is still in process of expansion and development. For even at the present rate of advancement what may happen electrically in the next fifty years staggers the imagination. Industry has not yet learned how to use it to the utmost.

Railroad Transportation in America

By W. H. TRUESDALE
Chairman of the Board of Managers
Lackawanna Railroad

IN 1877 there were 79,082 miles of railroad in the United States. By comparing that figure with 264,233 miles in 1920, it will be seen that the railroads have developed immensely in fifty years. Carloadings have jumped from 631,740,636 tons in 1890 to 2,466,427,267 tons in 1925. No records of carloading prior to 1890 are available.

Fifty years ago locomotives were comparatively light. They were equipped with pumps as well as injectors. The air brake was coming into general use on passenger trains but had not been applied to freight trains. The Stephenson link was the only available practical valve gear. The D-slide valve reigned supreme. There were no superheaters and no boosters. Weight and tractive force were all that were necessary but were very small in comparison with the values of today. Automatic couplers and vestibule trains were unheard of. The first steel freight car was introduced in 1890, and the standard track gage was adopted in 1897.

The weight of the largest locomotive in 1880 was 101,701 lb. and the tractive force was 23,000 lb. Today there are in common service locomotives weighing more than 500,000 lb., with tractive forces exceeding 127,000 lb. Operation has been revolutionized by gasoline and gas-electric passenger cars, locomotive boosters and automatic train control. Track work is a different job by reason of the air tool and the railway motor car.

The total capitalization of railroads in 1877, including the funded debt, was $4,568,597,248. This figure is to be compared with $21,795,241,424 for 1925. There were in service in 1877, 15,911 locomotives, 392,175 freight cars and 12,053 passenger cars. In 1925 the figures were 68,035; 2,415,037; and 56,915 respectively. A standard rail fifty years ago weighed 60 lb. per yd., and was made of Bessemer steel. The rail of today weighs from 100 to 136 lb. per yard and is made of open hearth steel, with percentages of manganese.

AS THE country developed the railroads had to develop. Perhaps it is more nearly true to say that without expansion of railroads and development of the mechanical equipment the country could not have developed as it did. To stimulate the railroads to greater activities in the work of expansion, subsidies were given them to assist the opening of the Western country. This great movement of the railroads to and through the West has been of outstanding importance to the United States.

The condition of railroad repair shops naturally parallels the condition of the railroads themselves, being a reflection of policy and financial condition. Fifty years ago there were not many machine tools designed especially for railroad work. There were driving wheel lathes in which a good mechanic could turn a pair of tires in about 8 hours. Today, on modern equipment, a mechanic no better than the first can do the same work in about 45 minutes. There were quartering attachments and a few car wheel boring machines, but practically no other types of single purpose machines.

There were no drawcut shapers, few radial drills, no planer-type milling machines, no open-side planers, no crank planers, no compressed air equipment in the shop, no electric or gas welding equipment. Cylindrical grinders and hydraulic presses were of insufficient capacity for the work that would have had to be done. No thought had been given to the cooling of cutting tools by the flood method, with coolant later collected and returned to the system. Flues were cut out by chisel and hammer and safe ends were welded in the fire. There were no electric cranes of any description and material handling equipment was crude.

WITH the increased demand upon the railroads, loads became heavier, requiring improvements in road beds. Hauls had to be longer which meant that locomotives had to be more capable. Repairs had to be better made. It was found that the value of the locomotive in service was so much greater than the value of the same engine in the repair shop that the shops were improved and better equipped to reduce the shopping time.

This demand for shorter shopping time resulted in a demand for special tools. Before they were developed the need for them was responsible for the construction of certain home-made devices that proved to be the forerunners of some of the present-day special purpose railroad tools. In other words, the necessity for greater production to accompany the natural growth of the country and extension of the railroads caused a swing by the machine tool builders toward special tools. This swing lasted only until the general purpose machine tools had been designed with sufficient strength and capacity to do the railroad work.

But every great modern war effects almost a revolution in the machine-tool industry. In addition, locomotive runs throughout the country have been practically doubled, and the mileage run by every car substantially increased. As a result, both the opportunity and the need for further shop improvement is at hand, and maintenance of equipment assumes a still more prominent position in the field of railroad operation.

In response to this fact the expenditures by the railroads in the past few years on new shops, power plants, tools, and material-handling machinery have been substantially increased. Provided sufficient new capital can be obtained by the railroads, this process will continue.

Ordnance Developments in Fifty Years

By GEN. C. C. WILLIAMS
Chief of Ordnance, U. S. A.

THE world has witnessed in the last half century the greatest developments in ordnance materiel in the history of all times. As the rapidly growing industry of the country has developed methods and facilities of production under the spur of increased transportation facilities and wider markets, ordnance engineers have applied as much of these achievements as was applicable to their particular problems, with the result that we have today weapons of accuracy, power and mobility undreamed of by the soldiers of fifty years ago.

Among the outstanding features of this development, which might be cited as examples of progress, are the following: Steel guns and carriages, smokeless powder, long-recoil rapid-fire guns, automatic weapons and machine guns, anti-aircraft guns, large-caliber railway and seacoast guns, tanks, tractors, self-propelled gun mounts, armor plate, armor piercing projectiles, aircraft bombs, and the accurate fire control equipment necessary for the expert use of this highly developed materiel.

The high quality of modern ordnance, its precision and accuracy, have largely been made possible by the remarkable efficiency of our present-day machine tool equipment.

IT IS of interest to note that Henry Bessemer, concluding that if any advance was to be made in artillery, better metal must be available, established his iron works in St. Pancras, which led to the process of steel making for which he is famous. As a result, steel guns were made. A few years later smokeless powder was discovered. Higher powder pressure could then be obtained and controlled, and the power of guns was increased tremendously. Increased pressures demanded increased strength in gun walls, old principles were applied, and modern facilities employed to produce an initial compression of the bore by means of shrinking on hoops, wire wrapping, and finally by creating the compression by cold-working under great interior hydrostatic pressures.

As a result of this increase in power, far greater accuracy was demanded and scientific methods were developed for the purpose of enabling the gunner to hit the target at the longer ranges with the minimum expenditure of ammunition. Ballistics as a science has been improved, and so has its application; fire control methods and instruments of great precision have been brought out; and aircraft have been called upon to make possible the observation of fire.

But in this age of transportation we cannot neglect to mention the effect that transportation has had on ordnance. It is no longer sufficient to mount a weapon of great power, but this weapon must be moved about if it is to serve its purpose of assisting the advance of armies. Here the internal combustion engine is fast showing itself to be indispensable. Tractors more and more are being relied upon to draw all but the heaviest types of artillery. Pieces of such weight that they cannot be moved on the roads are mounted on railway carriages, an idea that had its conception in the Civil War.

For the purpose of the maintenance of these advanced weapons, mobile shops have been provided, equipped with machine tools of capacities ample to handle all but the heaviest work and major overhaul, which are done in the Government arsenals. When it is realized that at the present time the Ordnance Department of the Army handles in the neighborhood of 250,000 major articles of issue, which range in magnitude from needles to 16-in. guns, and in variety from watches to railway mounts, it is understood that maintenance is no small undertaking as compared with 300 articles of issue fifty years ago.

THE problems of the Ordnance Department in 1877 were not unlike those of today: a large stock of materiel of Civil War manufacture was on hand and rapidly becoming obsolete; new models of greatly improved characteristics were under development, but development was hampered by lack of funds; old materiel was being modernized as rapidly as funds could be secured; and there was a limited manufacturing program, principally confined to small arms, machine guns (Gatling) and ammunition therefor.

The cost of ordnance equipment used by an army has increased over 500 per cent in the last fifty years. It may be asked, then, where does the Government expect to obtain the vast quantities of materiel which would be needed in case of a major emergency. The industry of the country must be depended upon to supply it. Previously the responsibility of the Ordnance Department for the supply of materiel commensurate with the idea of the nation at war was recognized, but the larger aspects of Industrial War Planning as we recognize them today were unknown. Once the policy was to enlarge the arsenals, to accumulate stocks of arms, and to make the Department so far as practicable independent of industry. Today our arsenals, as a matter of fact, are the experimental plants, which would also be used for the early production of the most urgently needed materiel in case of emergency. The large production of materiel required by a major emergency will have to be met by the whole industry of the country. To this end, the Department is co-operating with the leaders of industry through the Ordnance District Offices, of which there are fourteen scattered at strategic points throughout the country. Very close contacts are being made with manufacturers, and many allocations of ordnance to be furnished by each in event of a major emergency have been made.

Engineering Education and Industry

By DEXTER S. KIMBALL
Dean of Engineering, Cornell University
President, American Engineering Council

THE task which the editor has laid upon me of writing in brief the story of engineering education during the last fifty years is a very difficult one since that is almost the entire story of this great development that has changed not only our daily lives, but our entire outlook as to the future. It was inevitable that the great growth in scientific thought during the first part of the last century should be reflected in our educational processes. These scientific developments greatly broadened our vision by holding out hope of a more complete conquest of our environment and of elevating the physical condition of all mankind, a hope that has been in some measure already justified. The old arguments and criticisms as to whether technical education is "real" education and as to its place in our educational structure are now of little or no consequence. Technical education has justified itself in so many fields from shoemaking to medicine as to leave no doubt as to its permanence and importance. There remains only the question of its organization and content, a question so vast as to be outside the scope of this article.

One of the first recognitions in this country of the value of technical training was the founding in 1794 of the United States Military Academy now situated at West Point. In the original plan of this institution provision was made for the formal training of military engineers. The first private technical institution in America is the Rensselaer Polytechnic Institute which was founded in 1824. The greatest impetus that technical education has ever received in this country or elsewhere, however, came from the Morrill Land Grant Act of 1862 which made possible the great State Colleges of "Agriculture and the Mechanic Arts" which are so profoundly affecting our educational ideas.

THE influence of the *Machinist* and other pioneer journals has been most notable in one particular phase of engineering education. Engineering education unlike some other scientific callings did not grow out of the practical experience of engineers. As Mr. Wickenden accurately states: "Engineering education in America, practically from its inception, was in all essential respects a form of collegiate education; it was instituted and directed by educators rather than practitioners; it did not evolve from apprenticeship, and only slowly and partially replaced it; it was never on a proprietary basis; and it gained the patronage and support of practitioners with considerable struggle." As a consequence the early efforts at engineering education were looked upon, perhaps justly, with distrust by practicing engineers.

It required many years to show that both theory and practice are essential factors in engineering work. Today the progressive teacher seeks industriously for the practical verification of his theories before presenting them to his students. And, on the other hand, his product in the form of graduates find ample opportunity in the industrial field and his writings and text books form the most important part of the literature upon which modern engineering is conducted. The wise practicing engineer long since laid aside his caustic criticism of educational methods and is doing much to help the educator find that nice balance between theory and practice that will enable him to prepare young men adequately for the complex functions of modern industrial life. Without doubt the technical press has done much to bring about this result. By publishing the results of scholarly research alongside of the findings of practical men, by opening its columns as a forum for the discussion of the entire field of engineering, both theoretical and practical, it has made its own peculiarly valuable contribution to the advance of engineering education.

IT SHOULD be noted, also, that the scope of engineering has broadened tremendously in the last half century. Even thirty years ago engineering was by definition confined to the design, construction and operation of engineering production. About that time, however, the engineer began to apply his methods to the problems of industrial administration with such success that his methods are becoming almost universal in industrial management. Today the terms "engineer" and "engineering" have almost lost their original meaning and have become synonomous with *systematic accomplishment* and with "getting things done." This extension of the work of the engineer has naturally brought him into close contact with the *economic problems* of industry and he promises to make almost as great a contribution in this field as he has made in the field of the mechanisms of management.

Lastly, these excursions into new fields have brought the engineer face to face with the broader problems of human existence, and particularly with that basic problem, the equitable distribution of the wealth that his methods create. To help in this difficult problem he comes poorly prepared, lacking both economic and historical background. Here in these last two fields lies his greatest opportunity and if he is to reach his highest development the engineering college must include in his preparation the elements of a broader culture. To this end, the three great influences that shape his development, namely the college, the practicing engineer and the technical press must now address themselves. Here is a problem worthy of the best that is in them and I prophesy that they will not fail to respond to the need.

Pioneers and Progress in the Air

By Glenn H. Curtiss

THE conquest of the air is one of the outstanding achievements of the last half century. And there is credit enough for all who have helped to bring aviation to its present stage of development to let us pass over most of the points of dispute regarding priority in the use of certain devices. The one exception is in regard to Professor Langley's "Aerodrome."

There is little doubt that Professor Langley went to an untimely grave because of the ridicule over the failure of his great flying machine. Few would believe that its dive into the Potomac River was due to a defect in the launching way and that the machine itself was inherently right. Yet this was proved years later, when I personally flew the Langley machine. It had the original motor, transmission, frame and much of the original woodwork and wiring. No changes were made which could in any way affect the flying qualities of the machine; in fact, the pontoons which were attached for the purpose of starting from the water not only added some three hundred pounds to the weight of the machine but caused a great deal of head resistance. These of course added to the difficulty of flight. The fact that the Langley machine would fly was obvious to any unprejudiced aviator or aeronautical engineer. It was only the question of controllability which was uncertain. The dihedral angle to the wings gave it inherent lateral stability. The rudder was ample and fore-and-aft balance was a matter of proper adjustment of the elevator.

It must be remembered that at the time of Langley's attempts to fly, his problem was first to sustain flight over the water for a limited period only. After he had proved that this could be done, it would have been easy to get financial assistance to carry on experiments to develop suitable landing gear and improve the controls. The goal at that time was for a human being to sustain himself in the air for even a short time.

TO Professor Langley belongs great credit, for he produced a flyable machine even though it did not fly for many years after its first unsuccessful attempt. So far as I know, no one questions that the Wrights were the first to fly. The fact that the Langley machine was capable of flight does not in any way, as I see it, detract from the glory of the Wrights' accomplishment.

Most of the readers of the *American Machinist* know, in a general way at least, of the progress that has been made in aviation, for this publication has from the first devoted much energy and space to recording the advances made, even before aviation began to assume a commercial aspect. As early as June, 1909, the *American Machinist* devoted several pages to an article describing the work at Hammondsport with the June Bug and the Silver Dart and later in the year gave a similar account of experiments at Cape Breton, Nova Scotia.

Since that time aircraft development has been more or less spasmodic. The great need for planes during the war led to tremendous expansion of building facilities but the desire to build only something new in design instead of utilizing the best then available, caused much delay. And but few of the new designs proved satisfactory. Perhaps the best aircraft development of the war was the Liberty engine, which still functions well. But the great surplus supply of these engines has delayed the general adoption of those of more modern design, for the Liberty is now ten years old—and ten years has seen big strides in all that pertains to aviation. As an example of this we have only to compare an army D.H. with a modern commercial plane to find that the modern plane will out-perform it in speed, climb and weight carrying with an engine of not much over half the power of the Liberty.

MUCH progress has also been made with lighter-than-air craft. The relatively large costs involved have hampered pioneering in this field but the achievements of the night bombing Zeppelins during the war and the transatlantic flights since are epoch-making. There is every reason to believe that they will find their place in the economic scheme and develop rapidly. The use of helium eliminates the fire peril and the experiments with metal skins show promise.

The persistent efforts of the Post Office Department have been of the greatest encouragement to aviation. The increase in night flying, this also being fostered by the Post Office people, has been made possible by an increasing use of instruments and the development of air beacons and the illumination of landing fields. Commercial flying is increasing more rapidly than those not interested in the industry realize. Municipalities are providing more and more landing fields and are making the names of the cities and towns on the roofs of large buildings.

The new air mail contracts will help to encourage more commercial lines and the next generation will grow into traveling by air just as at present we depend on the automobile. This does not mean that railroads and motor cars will disappear. It only means that a newer and faster mode of travel has been found to take its place with the others, for the kind of travel service to which it is best adapted. Long distance travel, both for passengers and for valuable mail or packages, will be done more and more by air, perhaps as an auxiliary service by the railroads themselves.

Standardization and Its Effect on Industry

By GEORGE K. BURGESS
Director, National Bureau of Standards

THE phenomenal development of the standardization movement has been accomplished almost wholly within the past half century, and the greater part of this growth lies in the last 25-year period with constantly increasing activity from decade to decade. Recently even the progress from year to year is marked with substantial contributions and extension of scope, affecting international as well as national relations, securing economies of production and distribution, improving the standard of living and influencing in many ways advantageously our whole modern civilization.

In no field of activity has the progress in standardization been more fundamentally sound, more generally effective, more widespread, more beneficial, and perhaps nevertheless more difficult, than in those industries for the advances in which the mechanical engineer is mainly responsible.

In the mechanical field, our fifty-year period is antedated by Whitworth of England who in 1840 suggested a standard screw series with the forceful argument that as candles must be made to fit staple sockets, so screws should be of staple size and form to fit staple uses. In 1864 William Sellers of Philadelphia formulated his system of screw threads which has become the basis of the United States standard, although it took twenty years for the first large scale use in making bolts and taps.

In the United States today, such a state of uniformity has been reached for screw threads that one firm can and does manufacture over eight million bolts and nuts a day any two of which of the same nominal size will fit. At a recent international meeting in New York, screw products from a dozen American manufacturers were thrown together disassembled and then reassembled using indiscriminately one or another's products. Such are the results of standardization with gage control.

A SCORE of wire gages were known 50 years ago, and many of these are still in use with more or less confusion resulting. In general, however, the practice for individual commodities is fairly well standardized; for example, the steel wire gage (Washburn and Moen) is generally used for steel and iron wire, the American wire gage (Brown & Sharpe) for non-ferrous wires, and sheets (except zinc), and the U. S. Standard gage established by Congress in 1893 for sheet and plate iron and steel. Still other gages are used for drill-rod, piano wire, tubing, and other special commodities.

Progress in mechanics depends on the constancy, uniformity and reproducibility of the fundamental units of length, mass and time. To the astronomers we are indebted for our "second" which has always been accepted the world over; but for length and mass, the same happy situation does not maintain.

More than fifty years ago in Paris, 1875, was signed the first great standardization treaty—the metric convention. It established an international bureau of weights and measures for the construction and maintenance of reference standards of length and mass, and the construction and distribution of certified copies to the various nations of the world. Probably no single international co-operation has ever made a more enduring or more general service to the world. On a neutral tract, the Parc de St. Cloud at Sevres, Paris, is now located the first international standardization laboratory maintained by some twenty-eight nations. Fourteen years were well spent in the design and construction of the new standards for delivery to the nations.

FIFTY years ago Hilgard, then custodian of our standards said (Report of 1876): "Of the two standard yards presented to the United States, one is of bronze (No. 11) and the other of Low Moor wrought iron (No. 57). These are found to have changed their relative length by 0.00025 inch in twenty-five years; the bronze bar being now relatively shorter by that amount." Today, using the standard wave length of cadmium red radiation, suggested and first carried out in 1892 to 1893 by the American physicist Michelson, measurements fourteen years apart attest the accuracy of the world's standard of length to better than a part in 10,000,000—a constancy hundreds of times superior to that cited by Hilgard fifty years ago; and in addition, all material standards of length if destroyed might readily be reproduced by optical methods to as great an accuracy as could possibly be desired. Typical of this development are such researches as the inconstancy of alloys, the use of platinum and iridium, the non-expanding nickel-steel alloy (36 per cent nickel), the use of light waves as standards of length permitting the graduation of scales accurate to a millionth of an inch, the precise gage block system of unparalleled accuracy, and the ultramicrometer sensitive to a billionth of an inch.

It is of interest to look through the pages of the "American Machinist" and note the record of progress of standardization as it affects the mechanical industry, up through these fifty years. How far apart are the early references and how crowded together they became in the later years, and also how many of the early questions are still waiting a solution satisfactory to industry.

In 1882, for example, are references to standard taper of gas and steam pipe taps; an editorial advocating the re-establishment of the United States Board of Tests, which calls up the tremendous later activities of the

Federal Government; a statement that 3,000 car coupler patents have been issued and that the Master Car Builders Association hesitates to adopt any one of them as standard, a vivid picture of a patent situation as it affects standardization; and various articles on wire gages, a subject then being wrestled with by several organizations, illustrating a beginning of what has become a very serious condition, namely the multiplicity of agencies dealing independently with the same subject. In 1884 there is recommended the establishment of a Committee of the A.S.M.E. to consider standard parts for machine tools, and throughout the 80's are many standardization matters reported of interest to the railroads which were actively at work; boiler tests came up in 1884, culminating later in the standard boiler code of the A.S.M.E.

Of particular interest, in light of what has since occurred, is the report of a paper presented in 1889 before the A.S.M.E. by Mr. James W. See advocating the establishment as a Division in the Patent Office, of a government Bureau of Standards in which any respectable representative of a trade could file a standard. He stated government oversight would insure more accurate definition of standards, guard against confusion and provide for any interested party obtaining an accurate description of it. A bill embodying these suggestions was introduced in Congress in 1891. Professors H. A. Rowland and M. B. Snyder had previously, in 1884, presented to the National Conference of Electricians a report outlining a proposed National Bureau of Physical Standards. This was three years before the establishment of the first national technical institute, in Germany.

In 1895 first arises the question of the need of a standard hose coupling, while wire gages, pipe threads, tapers, machine tool parts, screw threads, and railroad materials continue to the fore; and in 1898 the quality of materials and test methods begins to receive more attention, illustrated by the activities of the American Foundrymen's Association on test bars and standard drillings, and the initial meetings of what was to become in 1901 the American Society for Testing Materials, starting as the American Committee of the International Association for Testing Materials.

THIS same year, 1901, saw the establishment of the National Bureau of Standards, as an outgrowth from a small nucleus having the custody of the standards relating to weights and measures in the Coast and Geodetic Survey, our oldest scientific government bureau. The growth of the Bureau of Standards in its fields of research, testing, and specification formulation in association with other national bodies, is familiar history, and an account of its development would leave but little space to mention other important standardization activities. It is interesting to note, however, how adequately this Bureau has met the needs set forth by such men as See, Rowland and Snyder, and kept pace with the ever increasing demands for the services it can and should render to the community.

In the meantime the standardization movement was growing by leaps and bounds. By 1917, there were literally hundreds of organizations publishing standards, most of which were formulated without systematic methods of co-operation or exchange of information among the organizations concerned. To meet this situation the American Engineering Standards Committee was formed as a body for correlating and promulgating standards.

There has nevertheless been maintained a tendency for each industrial or engineering group to retain control of its own standardizing projects; we need but mention as outstanding examples the railroads and the automotive industry. In its ten years' existence, the A.E.S.C. has been more successful in securing agreement on codes relating to safety and engineering practice, than on commodity standards in which more than a single industry is interested.

The World War greatly stimulated governmental activity in standardization. The National Screw Thread Commission, established in 1918, and made permanent in 1926, has set up standards and done much to encourage progress in the various industries covered by its field and co-ordinate their work. The Federal Specifications Board, created in 1921, has unified the multiple purchase requirements of the Federal Government and promulgated nearly 500 specifications, which are mandatory for all government purchases. Also in 1921, Secretary Hoover organized the Division of Simplified Practice which has developed a procedure by which many industries, including a considerable list of items in the mechanical trades, have found it possible to cut down the number of sizes, varieties, and grades of numerous commodities, resulting in savings running into many millions annually.

THE Bureau of Standards has issued a Directory of Specifications which gives a vivid picture of the needless multiplicity of specifications for commodities, and has in press a Standards Year Book describing the standardizing activities of the country; and is also working on a certification plan of particular interest to the small buyer who wants to purchase to a given standard.

Vast as is the standardization movement in this country, the activity abroad is also great, twenty countries having national standards associations; and the international aspects are rapidly beginning to take shape. For twenty years there has been in existence the International Electrotechnical Commission, and there are others relating to illumination and sugar, etc., while the national laboratories also co-operate by a procedure recently agreed upon through the International Bureau on matters relating to fundamental standards; Pan-American standardization has been started, and finally there is now in the process of formation an International Standards Association.

Where are we headed in this welter of standardization procedure which is itself far from being standardized? All mechanical engineers know that usually a machine having complicated functions to perform is first constructed in what we later recognize to be an unnecessarily cumbersome and inefficient form. We are still in that relatively clumsy state of development in relation to our standardization activities, and we may therefore now strive for simplicity and greater efficiency.

The technical men of the country have been doing a very difficult series of pioneer tasks for industry, but those responsible for industrial management are not yet generally awake to the fact that they as executives are alone responsible for bringing order out of the existing chaos in the field of standardization. We may expect this to be the next great step in advance for it makes for economy in production and distribution.

Fifty Years' Development of the U. S. Navy

By D. W. TAYLOR
Rear Admiral, Construction Corps, U.S.N., Retired

AT THE end of the Civil War the United States had the largest navy in the world, but fifty years ago, in 1877, it was at a very low ebb. Coincident with the decline of the American Navy, there were rather rapid and fundamental advances abroad. Just before our Civil War, there had begun in England and France the development of ironclads, largely as the result of Crimean War experience. This development was also influenced by the Monitor and Merrimac in the Civil War. During the same period the French Navy developed breech-loading rifled guns.

The crack ship of the U. S. Navy in 1877 was of 3,900 tons displacement, built of wood and having sail power. The ironclads of the navy were the single- and double-turret monitors carrying two and four smooth-bore guns, respectively. In 1877 there were only some 250 guns afloat in the entire navy, and of them less than 40 were rifled, these being made by inserting liners in the antiquated smooth-bore guns.

The first important step in the direction of modern naval development was not a provision for materiel, but for personnel. Two distinguished graduates of the Naval Academy were sent abroad in 1879 to take a three-year course in naval architecture at the Royal Naval College, Greenwich, England. Practice was continued for about 20 years and included courses at the University of Glasgow and L'Ecole Polytechnique, Paris.

As late as 1881, a naval board was of the opinion that "all classes of vessels should have full sail power." This seems remarkable at the present time, but the predilection for sail power died hard in the U. S. Navy.

Congress, in 1882, authorized the construction of two cruisers and the organization of an advisory board of officers and experts. Two more vessels were authorized the next year, these four making up the White Squadron of the navy.

THE next milestone was the initiation of an attempt to cure our weakness in building up-to-date ordnance. One handicap was the great difficulty in obtaining the necessary material in this country. When Whitney became Secretary of the Navy in 1885, he was convinced of the wisdom of purchasing up-to-date plans abroad, and finally bought complete plan for two sizes of cruisers and for a second-class battleship from British designers. By this time the naval officers who had taken post-graduate courses abroad were beginning to make their influence felt, and from Whitney's time on played a more and more important part in the design and construction of naval vessels. Some of them left the navy and became influential factors in private shipbuilding. Secretary Whitney also initiated the making of armor plate in this country, giving a large contract to a prominent steel company. He started a naval gun factory, and Secretary Tracy, who succeeded him in 1889, was able to begin the construction of any type or size of vessel with its armor and armament. Under Tracy the navy for the first time undertook the construction of the ironclad, now called battleship. The war with Spain was the great object lesson which educated the whole country along naval lines and caused a radical change in the outlook of the average citizen regarding the navy. The submarine, which played such an important part in the German campaign, began to materialize in this country about 1890. Submarine development was slow, being very difficult technically, and it was not until the striking successes of the German submarine early in the Great War that submarine construction was actively pushed and the development of offensive submarines undertaken.

THEN came the antidote to the submarine, the destroyer. This was originally a vessel of but 250 tons. The size gradually grew, until our standard destroyers during and after the Great War were of 1,250 tons, with nearly 30,000 hp. and developing about 35 knots. Battleships started in 1890 with the 10,000-ton, 16-knot Oregon class, carrying four 13-in. low-power guns and grew to the Iowa class, scrapped as the result of the Washington Conference, the vessels of which were to have been of 43,200 tons displacement, 21-knot speed and to carry twelve 16-in. guns.

The United States was early in the field with the armored cruiser type which, when introduced about 1890, was between the cruiser and the battleship. The British re-christened this the battle cruiser, and it soon became larger than the battleship. The theory of the battle cruiser was not very well borne out in the Battle of Jutland, when the British vessels were found to be much more vulnerable than had been supposed.

The development of the navy during the past fifty years has been almost entirely an engineering development. Starting from virtually nothing, it was necessary to develop our engineering designers, our shops and our shipyards. This was a slow process. The "know how" which comes from experience requires time, and it may fairly be said that for the first twenty years of the fifty we were learning the trade. These twenty years included a period of rapid naval development all over the world, but the extent of this development was no greater along naval lines than along other engineering lines, and there is at the present time no indication that development has ceased along the lines mentioned—either engineering or naval.

Research, the Basis of Advancement

By VERNON KELLOGG
Permanent Secretary, National Research Council

RESEARCH is a much used and much abused word these days. There are many kinds of activities dubbed research and many grades in each kind. But when the scientific man uses the word "research" he has a pretty clear conception of the "big idea" behind the word. Research means to him—and we may let it mean for us, writer and reader of this article—the attempt by a man or woman of more or less adequate scientific training and a greater or lesser stock of scientific knowledge to find out something new in the field of science.

The researcher may have either of two rather sharply contrasted motives for undertaking his research. One is that of finding out something new which can be made prompt use of, hence which adds at once to human power; the other motive is that of finding out something new about the order of nature regardless of any obvious utility of the discovery, hence something which simply adds to human knowledge. It is well to keep in mind, however, that as a matter of fact probably every addition to human knowledge becomes, in time, useful and adds to our power, that is, to our control and use of natural energy and materials.

We may speak, therefore, of research in applied or useful science and research in fundamental or "pure" science. These two phases of science are continuously referred to as if really different, but about the only real difference between them is that of the different motives of the devotees of each. The methods of research in both these phases of science are essentially the same.

MOST of the readers of this technical journal are probably more interested in applied science than in pure science, but it is especially research in pure science to which I wish to devote the few words of this article. I could tell you little, in these few words, which you do not already know about the extraordinary achievements in applied science which have been made in the last fifty years; but I may perhaps be able to tell you a few things not so commonly known about the achievements in pure science. I attempt this, especially because I want to impress upon you the truth of my declaration that the results of research in pure science, although achieved without utilitarian motive, always come in time to have utilitarian value. After all, science must be useful to be justified, although this usefulness, of course, may have a very broad definition.

Faraday's discovery of electromagnetic induction, a discovery in pure science made without motive of finding out anything useful, and with no such utility even dreamed of by Faraday and other physicists of his time, has made possible the whole of modern electrical industry in which six million people are employed directly or indirectly in the United States alone.

Maxwell's pure science mathematical discovery of electromagnetic waves and their subsequent detection in the laboratory by Hertz made possible the development of wireless telegraphy.

The whole art of broadcasting and receiving, nearly all long distance wave telephony, and all carrier-wave transmission of whatever sort, rest upon and grew out of pure science researches on the nature of electric discharges in gases at low pressures.

HELIUM, discovered in the sun by Lockyer in 1868, and extracted by Ramsay from cleveite in 1896 as a direct result of the knowledge of its spectrum thus gained, has greatly added to our knowledge of the constitution of matter and provided a non-explosive substitute for the dangerous hydrogen that had been used previously to inflate airships.

The marvelous development of the chemical industries, which are now producing synthetically from coal tar distillate most of the dyestuffs, antiseptics, high explosives, perfumes, flavors, and medicinals of commerce, became possible only after many years of painstaking pure science research had established the molecular theory of the structure of carbon compounds.

The great industry of paper manufacturing from wood pulp may fairly be said to have arisen from Reaumur's studies of wasps, which construct their papery nests out of materials produced by the mastication of bits of wood and other vegetable substances.

The germ theory of Pasteur, resulting in aseptic surgery and the preparation of serums which have saved millions of lives through the practical eradication of diphtheria, typhoid fever, yellow fever, and other fatal diseases, was the direct outcome of Pasteur's optical studies of the crystals of racemic acid.

THUS you see how all important pure science research has been as a fundamental basis for later applied science research. Useful knowledge of the greatest advantage to us has grown out of the results of research uninspired and undirected by any ideas of utility. The new things that are being discovered today by the pure science researchers will inevitably be the bases for new extensions of the useful knowledge of applied science. In fact, were all research in pure or fundamental science to cease, the fountains of applied science would dry up. Engineers and technologists should never forget this. They cannot be too friendly to the devoted pursuers of knowledge for its own sake, for such pursuit always results finally in knowledge for the sake of the convenience, comfort and health of mankind.

Progress in the Field of Power

By Fred R. Low
Editor "Power"
Past President American Society of Mechanical Engineers

FIFTY years ago the steam engine in its modernized form had little more than a century of development and use behind it. It had developed from the ponderous low pressure machine of Boulton and Watt to the factory engines of Corliss and his contemporaries. The ordinary boiler pressure for stationary work was under 100 lb., and 30 lb. of steam per hp.-hr. for non-condensing engines and 20 lb. for condensing were common figures.

In 1879 the U. S. Census gave 2,185,000 hp. of prime movers installed in manufacturing establishments of the country, or 0.8 hp. per wage worker. By 1925 a total of 35,770,748 hp. had been installed in industry, or more than 4 hp. per worker. But this is only part of the story. The last half-century includes practically the whole history of the electrical industry, which in that time has reached a total installed generator capacity in central stations of 22,000,000 kva., or approximately 29,500,000 hp. This equipment turned out a total of 61,158,857 kw.-hr. for industrial and domestic use.

The increase in height and capacity of office buildings, hotels, department stores, etc., with their use of electric service for lights, elevators and pumps, has added an unknown amount of power-producing apparatus to that in use in the smaller and lower buildings of half a century ago. Many of them, in fact, had no power plants at all. They were lighted by gas and their tenants climbed the stairs.

The refrigeration industry, too, is largely a development of the last half-century, and the power required for the operation of its machinery is no inconsiderable amount. The period of which we speak has seen the creation and extension of the entire automotive industry. While in the individual automobiles, trucks, tractors and airplanes, the power units are of comparatively small capacity, the aggregate amount of power developed is represented by figures that are staggering.

THE internal combustion engine for stationary use has advanced from the little gas engines driving coffee grinders and small printing presses, to Diesel units of 5,000 hp., developing 750 hp. in a single cylinder, and generating a hp.-hr. on 0.4 lb. of oil, converting its heat contents into mechanical power at 34 per cent efficiency.

In the quarter-century preceding the birth of the *American Machinist*, Corliss had established the superiority of his type of engine, taking, at first, his payments out of the savings over those of the engines then in use. His great beam engine built for the Centennial Exhibition, with its system of power distribution by means of shafts and gears, was typical of the practice at the beginning of the period of which this anniversary issue treats.

The need developed for an engine to which the generator could be directly attached and driven at high speed. This service demanded nice regulation, and the single-valve automatic cut-off shaft-governor engine made a serious inroad upon the market.

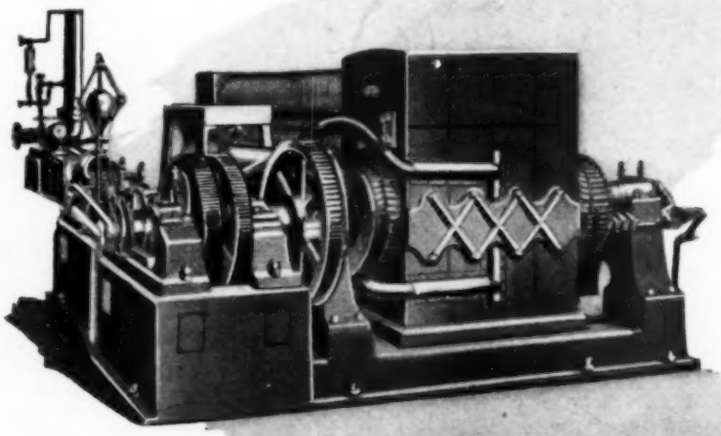
In the early '90s, De Laval appeared with his steam turbine, a disk scientifically designed to withstand the centrifugal stress due to 30,000 r.p.m. and ingeniously mounted upon a flexible shaft, so that it could find its own center of rotation, carried in bearings cunningly devised to dampen out vibration.

THE modern steam-turbine with its accurate workmanship, its precise fits, its delicate balancing, its intense temperature and its whirling stresses, had to await the production of materials, the perfection of tools, and the training of workmen to a degree of precision unknown to the earlier engine builder. It is a far cry from the day when Watt rejoiced in the success in fitting a piston to a cylinder so neatly that a sixpence would not slip through between them, to that in which rotors of many tons in weight turn on bearings at 3,600 r.p.m. in perfect running balance and with clearances between their surfaces and those of the stationary parts that are measured in thousandths of an inch. The possibility of the modern steam turbine is due in no small degree to the perfection of the machine tool and the skill of the modern machinist. The development of turbines of huge capacity, and staged so as to run within the speed for which generators could be built for direct connection to them, is a matter of history.

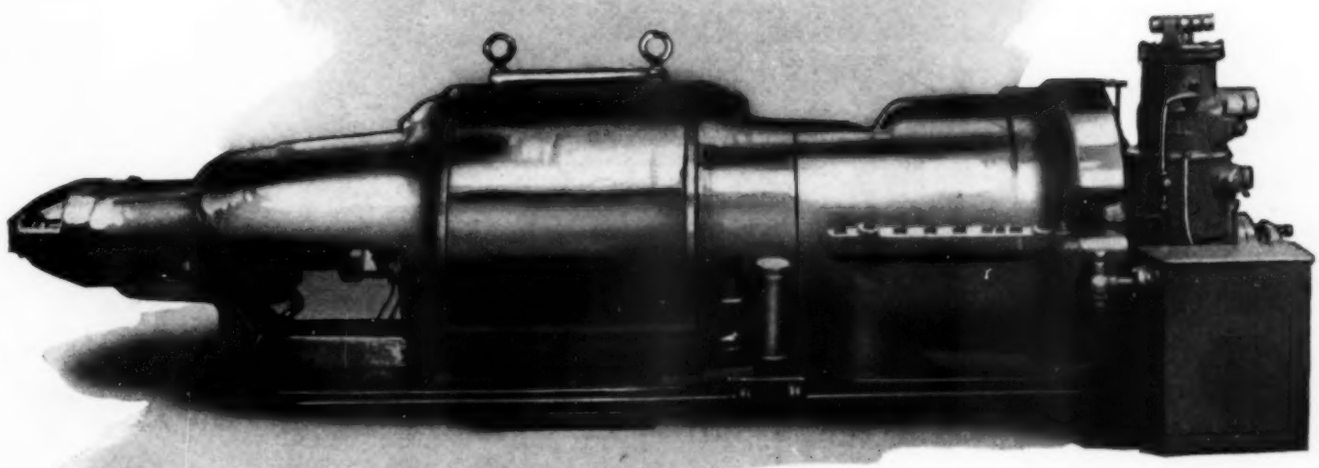
Boiler pressures have gone up until 300 or 400 lb. is not uncommon in the newer installations, and a boiler to carry a pressure of 1,400 lb. is being built for one of the power stations in Boston. Boilers have increased in size from the 3,000- or 4,000-sq.ft. units of fifty years ago, to 41,000 sq.ft. in a single setting, and ten or more pounds of water are being evaporated per sq.ft., instead of the three that used to be so common as to become the standard of rating. With increasing pressures and the improvements in manufacturing processes, the horizontal tubular boiler of the early days of the *American Machinist* has given place to the water-tube type, and even the furnace surfaces are commencing to be constructed of water tubes instead of refractory material. Superheat, after several fitful attempts, has come to be generally used in temperatures around 700 deg. Fahrenheit.

Many attempts have been made to burn coal in its pulverized form. Its successes, first attained in cement kilns and industrial furnaces, have been extended to power plant service, and it is now an active competitor of the mechanical stoker for power-plant work.

A Half Century of Progress



IN the following 8 pages are shown some of the machines of 50 years ago, and the modern types that make high production possible. They present an impressive record of the achievements of the machine designer

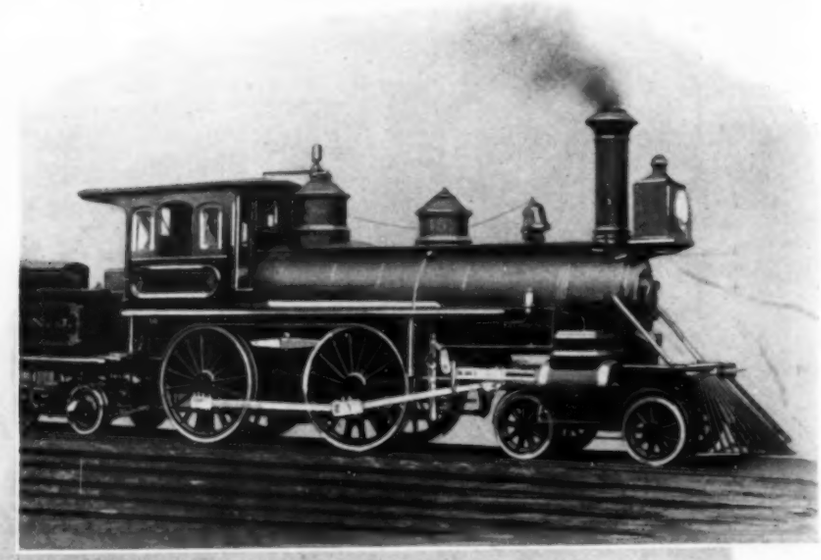


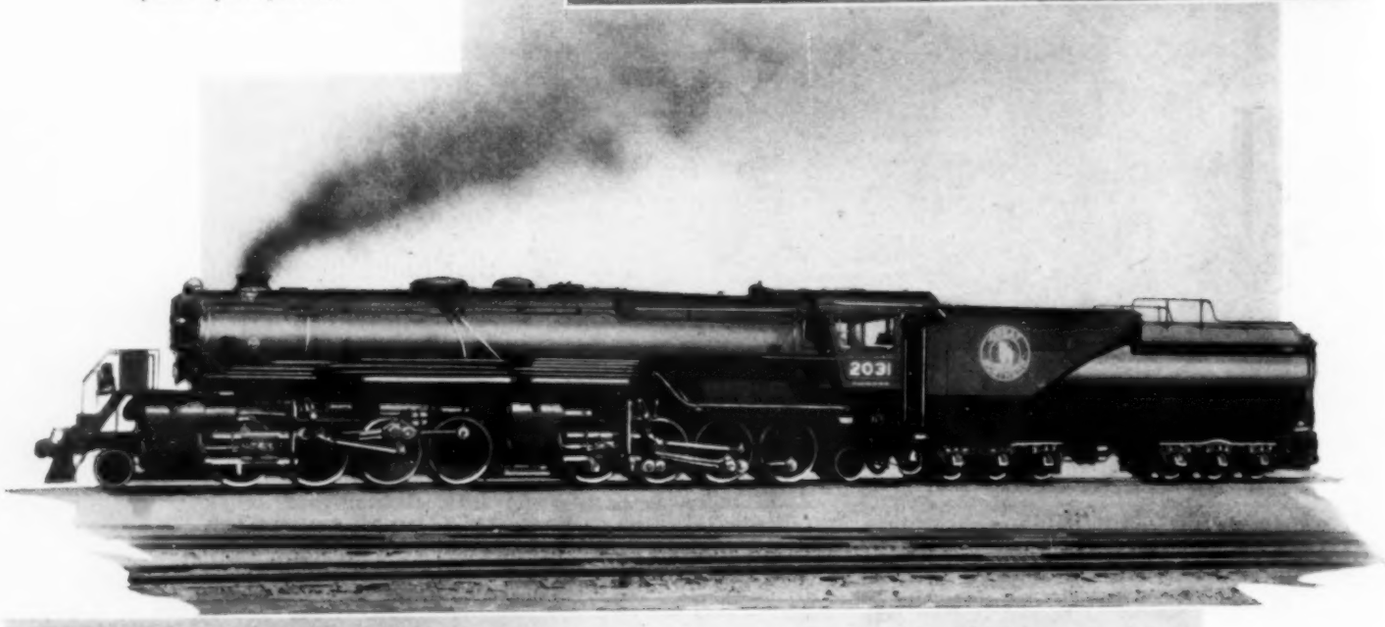
The electric dynamo built in 1882 had heavy multiple legs, and was a cumbersome unit. The steam turbine generator set of 1927 is compact and develops high power in proportion to its size

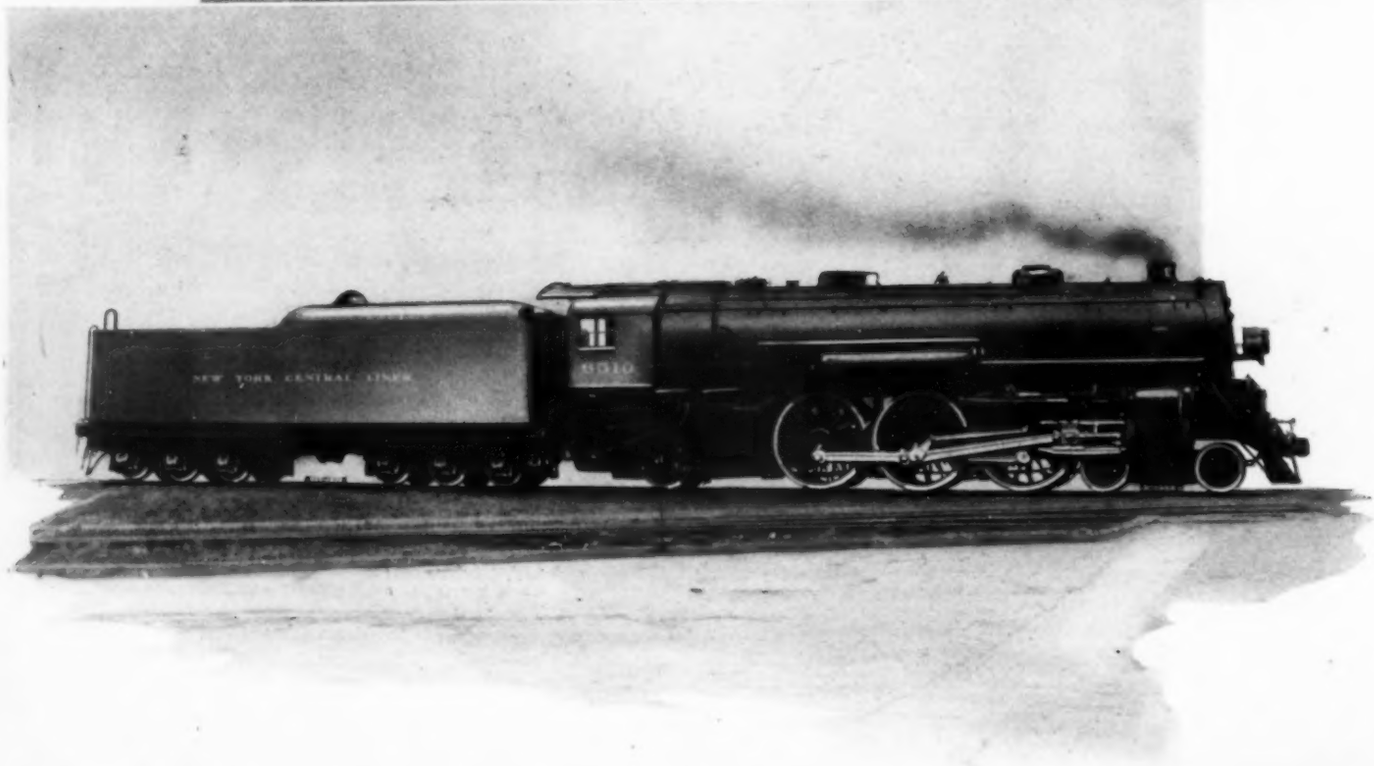
A half century of progress

Steam Locomotives

The Central Railroad of New Jersey locomotive 145 was built in 1875. It weighed 80,000 lb., used steam at 130 lb. pressure, and had a tractive force of 11,800 lb. The passenger engine shown weighs 362,500 lb. without the tender, uses steam at 225 lb., and with booster has a tractive force of 72,700 lb. The Mallet freight engine weighs 594,940 lb. without its tender and has a tractive force of 127,500 lb.

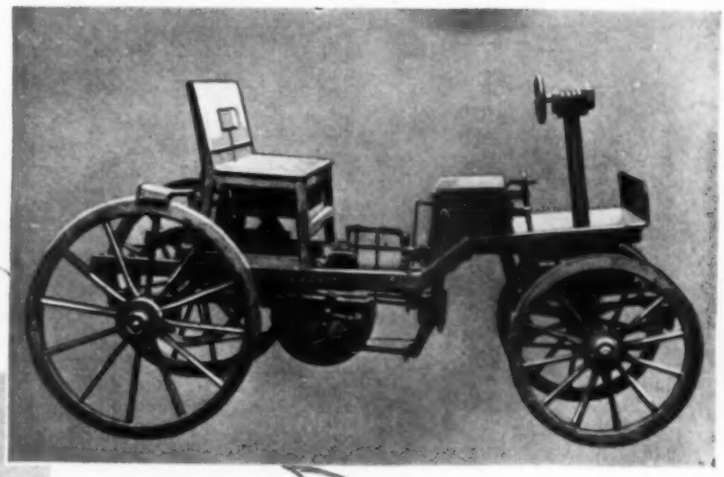


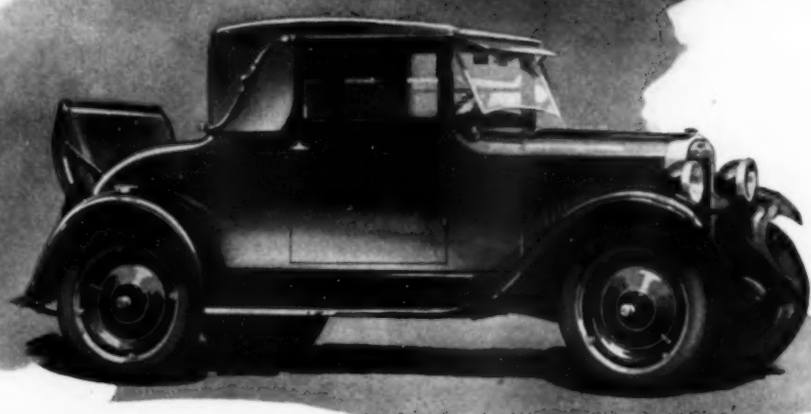




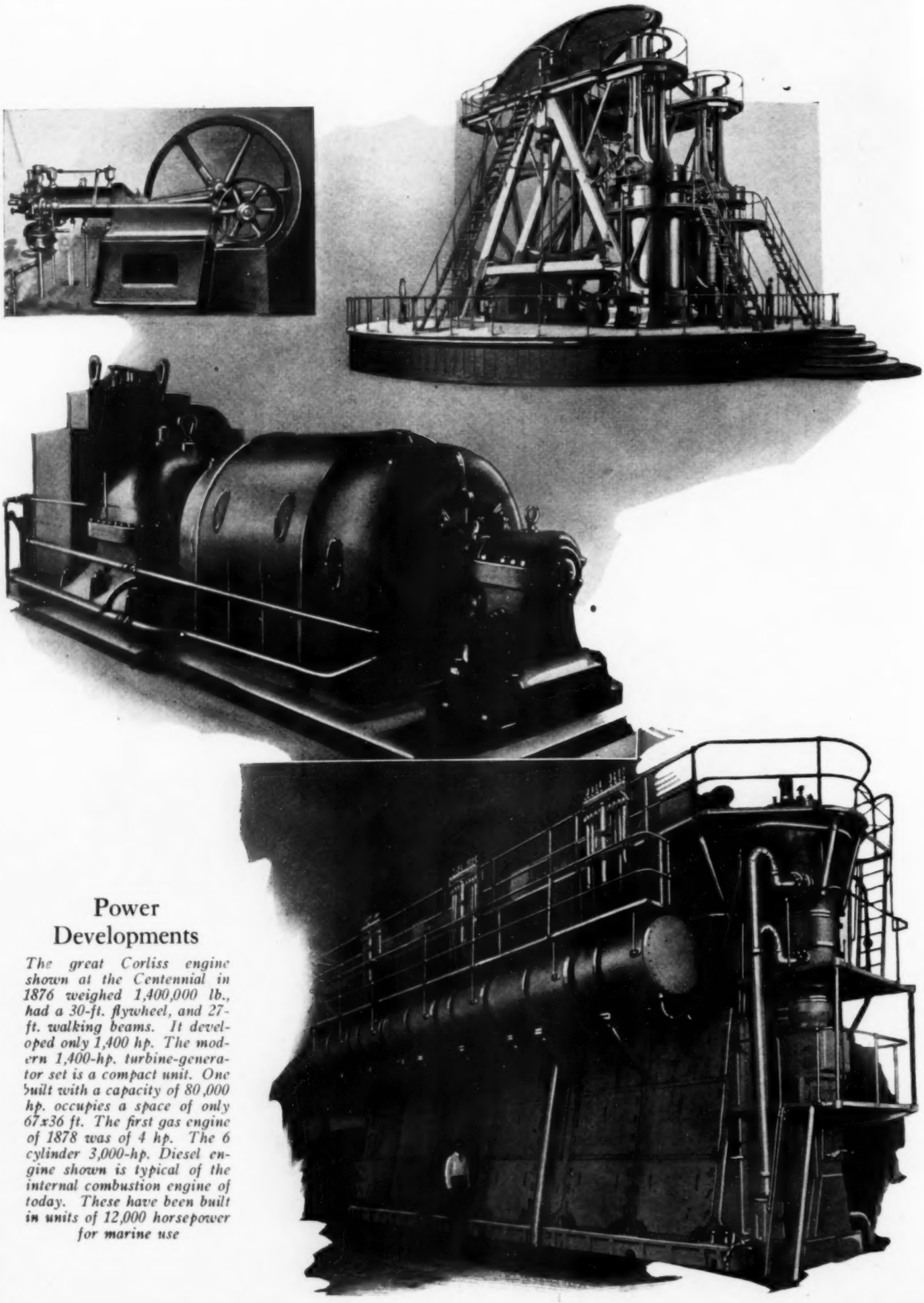
Automobiles

The first gasoline motor car was built in 1875. The first American automobile, shown in the upper left view, and on which the first American patents were based, was built just 50 years ago. The modern gasoline automobile is represented by the de luxe Town Car and the moderate priced Cabriolet Sport Coupe shown below



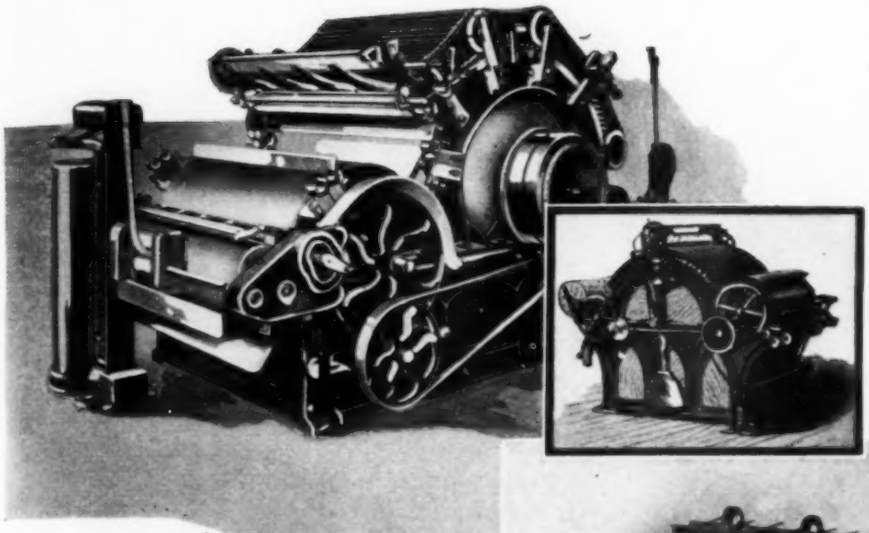


A half century of progress



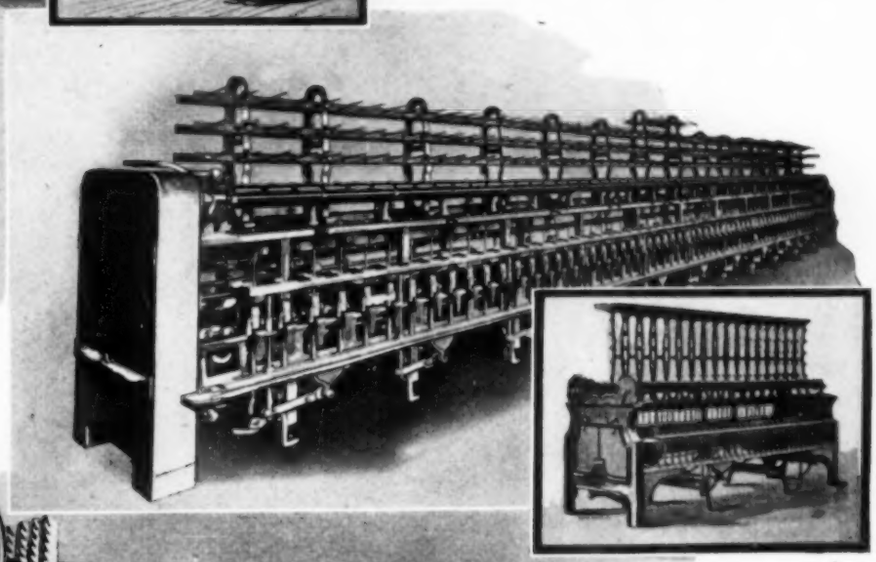
Power Developments

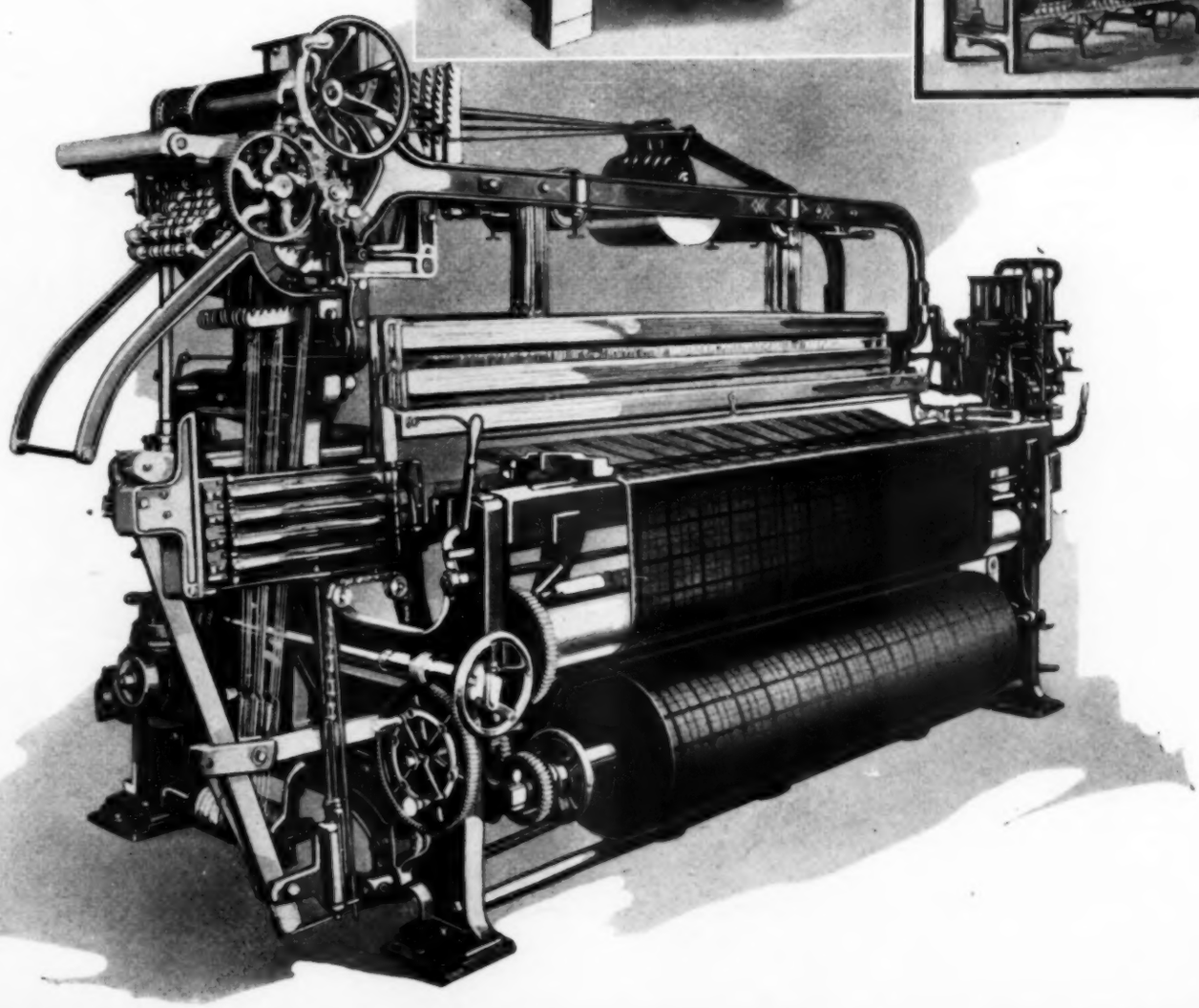
The great Corliss engine shown at the Centennial in 1876 weighed 1,400,000 lb., had a 30-ft. flywheel, and 27-ft. walking beams. It developed only 1,400 hp. The modern 1,400-hp. turbine-generator set is a compact unit. One built with a capacity of 80,000 hp. occupies a space of only 67x36 ft. The first gas engine of 1878 was of 4 hp. The 6 cylinder 3,000-hp. Diesel engine shown is typical of the internal combustion engine of today. These have been built in units of 12,000 horsepower for marine use



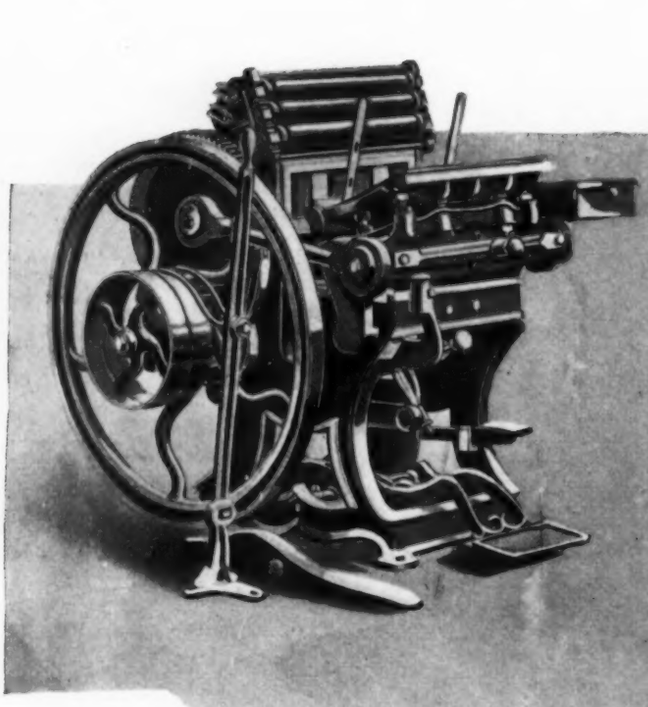
Textile Machinery

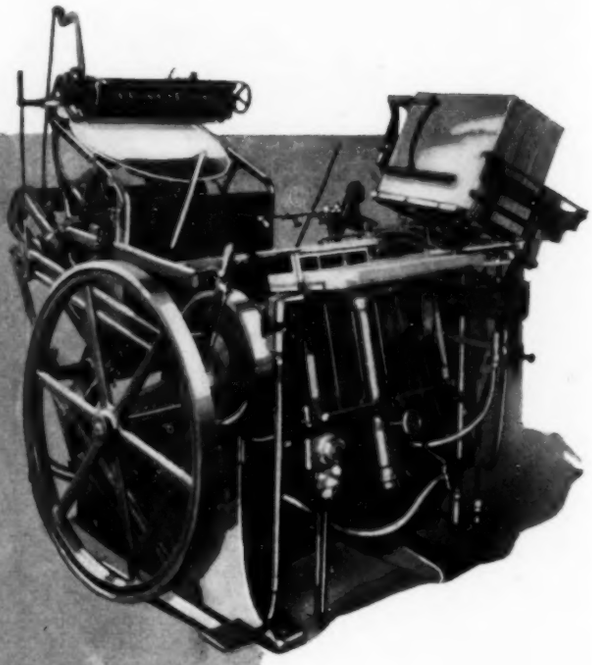
Textile machinery has developed in speed and efficiency. The present model of revolving top card produces 200 lb. of fiber per day with only 6 per cent of waste. The stationary top card of 1877 produced only 80 lb. with 12 per cent of waste. The modern twister has a spindle speed of 7,000 r.p.m., and makes an evenly twisted yarn. The twister of 50 years ago had a speed of only 4,700 r.p.m. The modern automatic worsted loom has multiple shuttles for mixing on fancy fabrics, and is motor driven





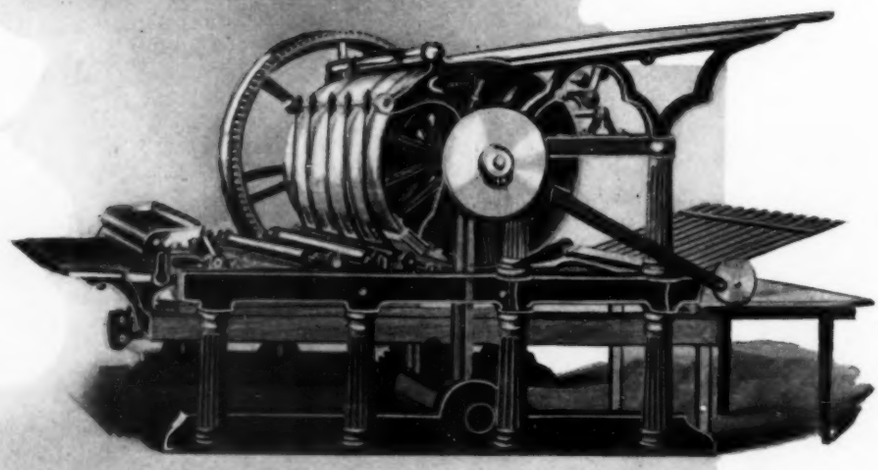
A half century of progress

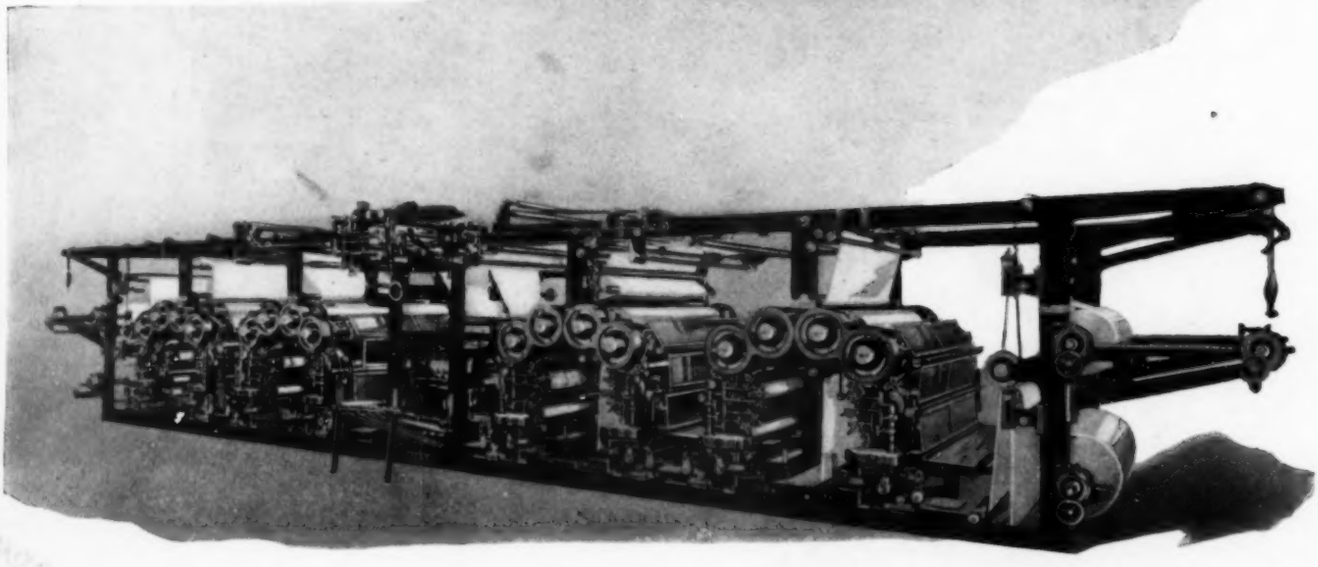


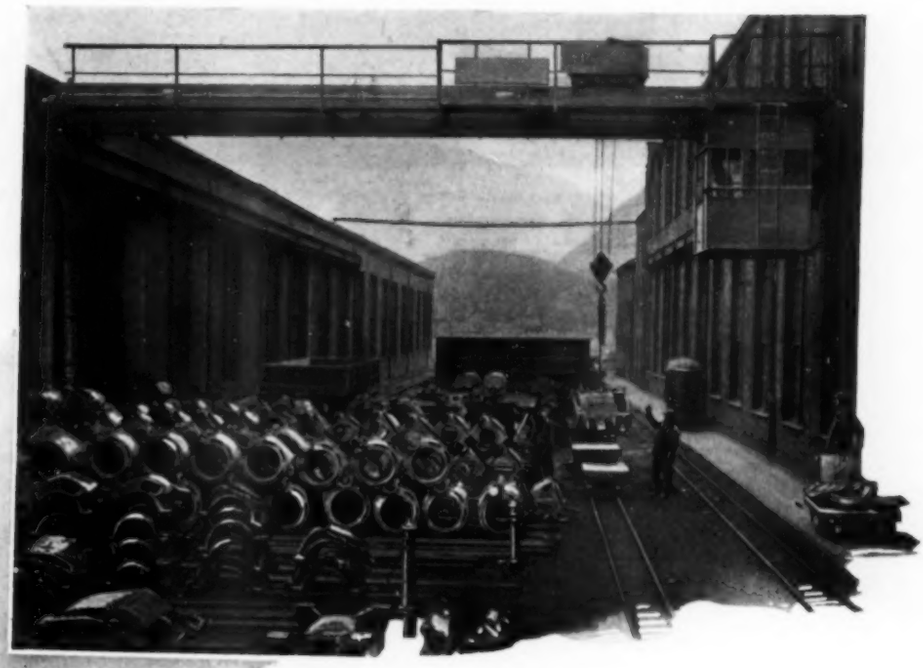


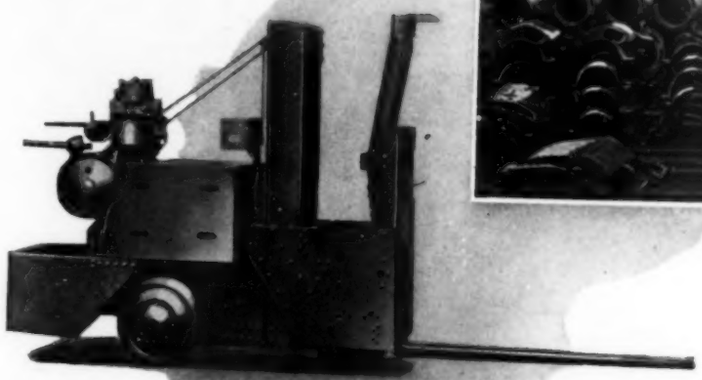
The Printing Press

The majority of job presses of fifty years ago were operated by a treadle. Likewise cylinder presses were of small capacity. All type was set by hand. The job press of today is equipped with automatic feed and delivery, and is motor driven. Newspaper presses now are entirely self contained and are automatic. Presses are built that will print and fold 216,000 eight-page newspapers per hour. The press shown in the last picture will print and fold 72,000 sixteen-page papers per hour



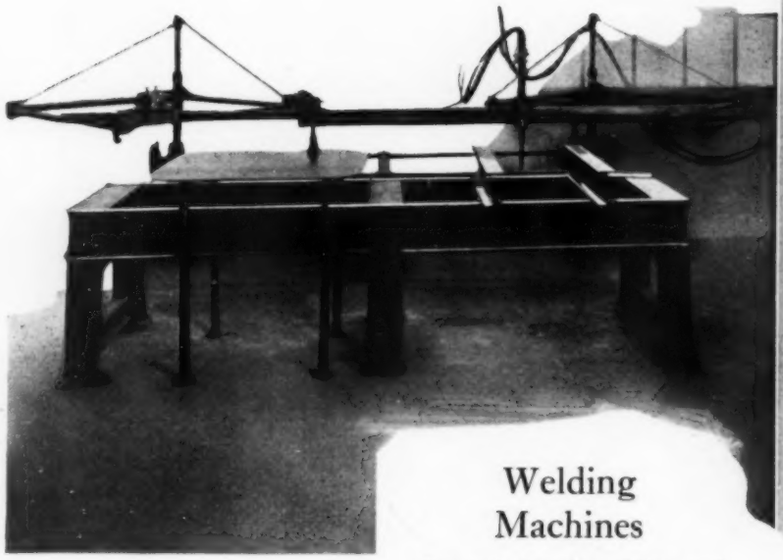


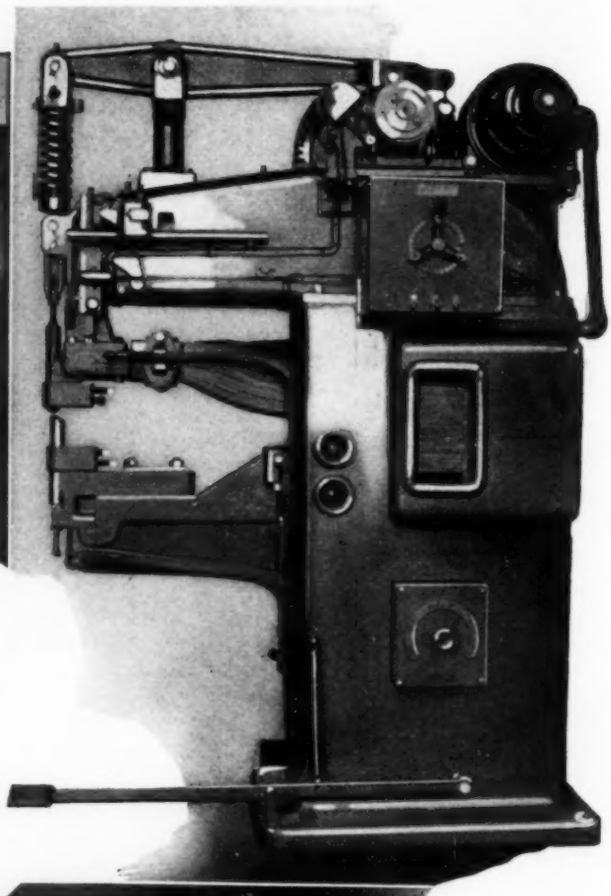




Materials Handling

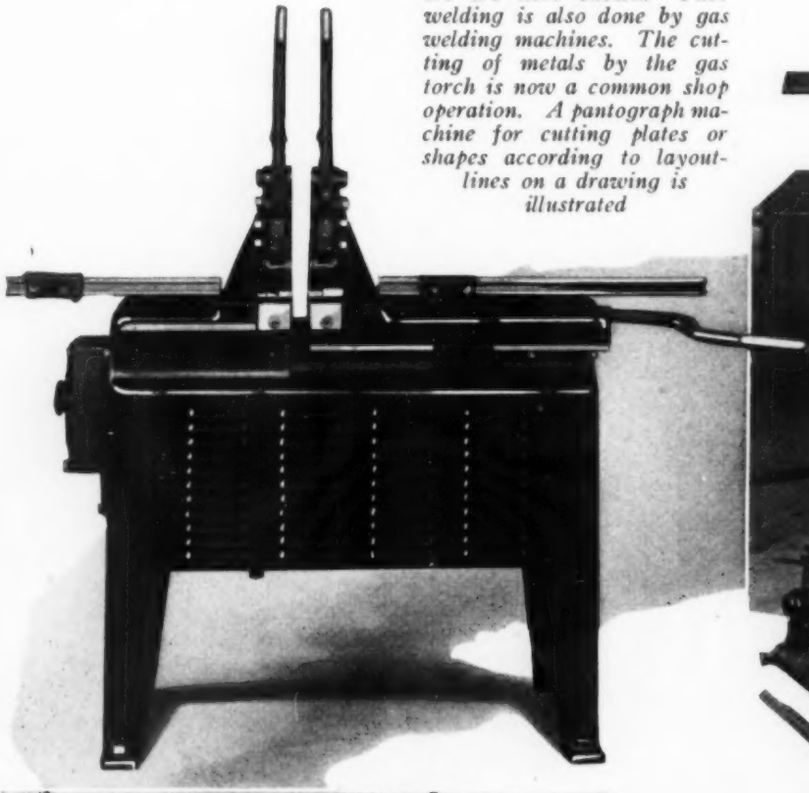
Mechanical handling of materials is a modern development. The electric traveling crane is adaptable to either the shop or the plant yard for serving machines, loading and unloading cars, and handling stores. The electric platform truck, the electric piler, and the electric hoist take the drudgery of materials handling from the workman. Roller and belt conveyors pass work from machine to machine in production shops

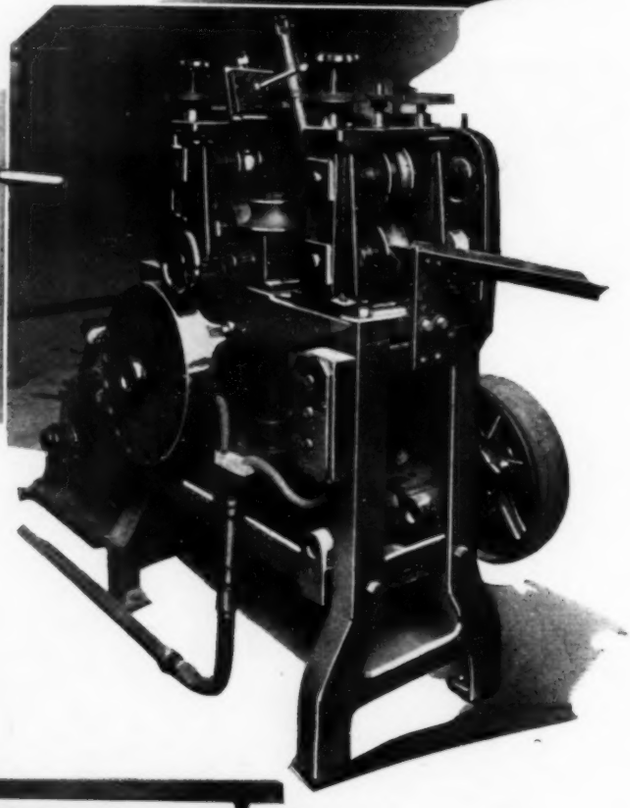


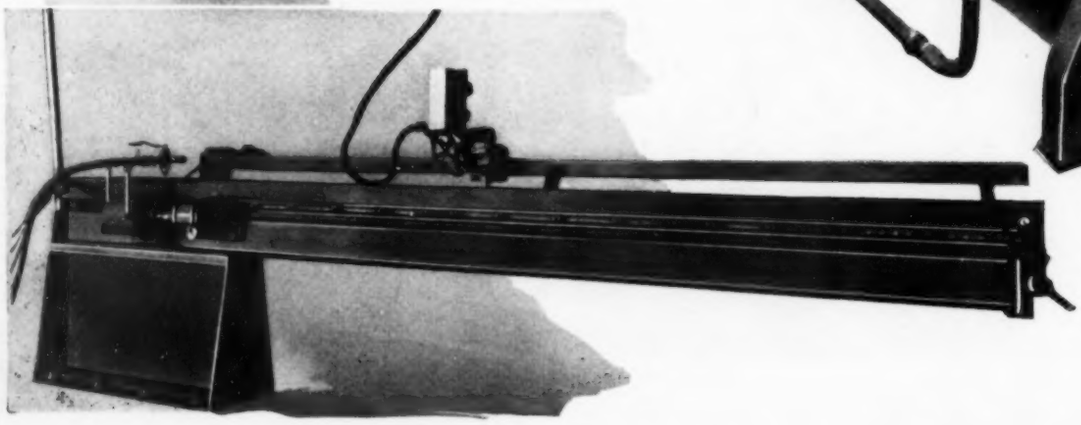


Welding Machines

Gas and electric welding and cutting machines are modern developments. Automatic electric butt, spot, and seam welders are here shown. Tube welding is also done by gas welding machines. The cutting of metals by the gas torch is now a common shop operation. A pantograph machine for cutting plates or shapes according to layout-lines on a drawing is illustrated







Equipment Since the Centennial

THE birth of the *American Machinist* was contemporaneous with the Centennial Exposition at Philadelphia in 1876—the first of a long series of great expositions displaying world progress in industry, art and science.

The industrial exhibits on that occasion well visualized the state of mechanical development of that time. One of the center points of interest of the whole exhibit was a walking beam Corliss engine, the greatest ever built up to that time, having the enormous authority of 1,400 hp. In 1926 an order was placed for a single turbine engine of over 100,000 hp. which probably occupies less floor space. A small electrical generator was exhibited, a sort of laboratory specimen, and today our generators of all sizes up to 100,000 hp. have a capacity of over 15,000,000 horsepower.

DR. BELL exhibited his newly invented telephone and it was regarded as a most interesting toy. Now 18 million telephones transmit 25 billion conversations per annum. At that exposition the public was greatly interested in the evidences of our fully developed railway transportation, yet less than 20 billion ton miles was the annual business, whereas today we carry 400 billion ton miles annually.

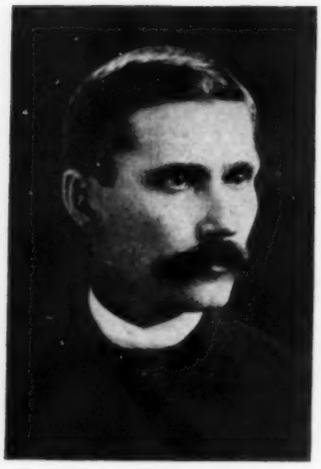
And there were no gas engines, no refrigeration, no radio. And there were but few of those great labor-saving tools of ten thousand varieties that have decreased human sweat and added to human comfort. But after all it would take an encyclopedia to record our mechanical progress.

WHILE we give proper place to the inventor and the courageous industrial leader in all this progress, one element is too often overlooked—the enormous contribution which the technical press has made to the development and diffusion of ideas. Without it no such era of progress would have been possible.

What is of more importance at this moment is the fact that the *American Machinist,* contemporaneous with this, the greatest period of mechanical development in history, has been the reflex, the stimulant, the guiding hand and faithful friend of all this development. It has contributed a great part through the constant development, the outpouring and diffusion of ideas which have dominated our industrial progress.

Herbert Hoover

Secretary of Commerce



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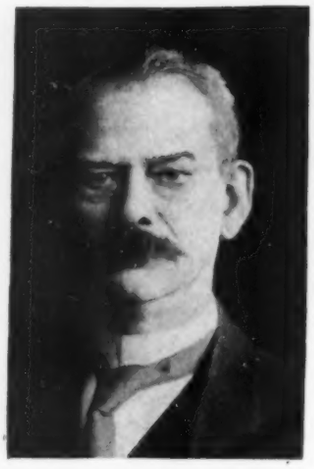

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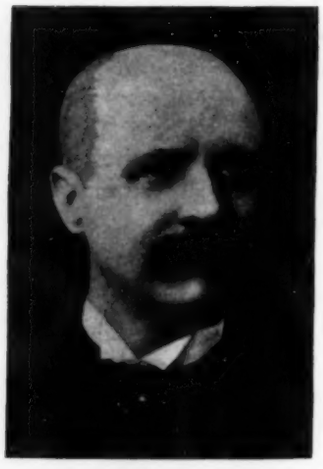

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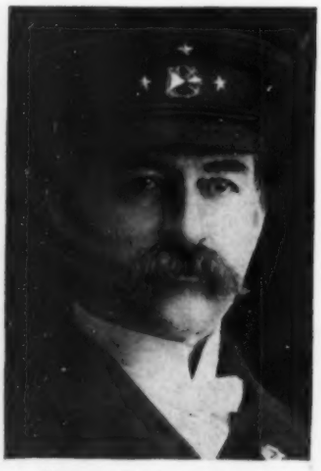
Men Who Have Made the American Machinist

1877—1927



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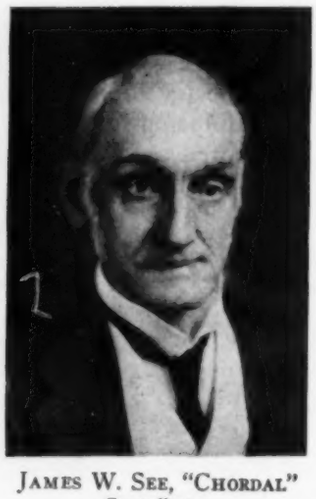

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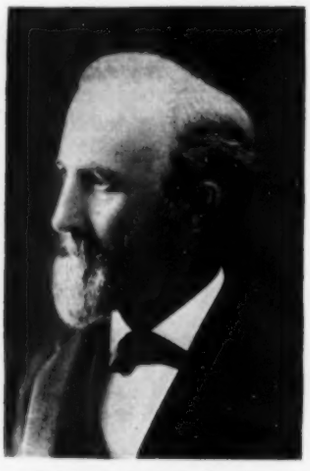

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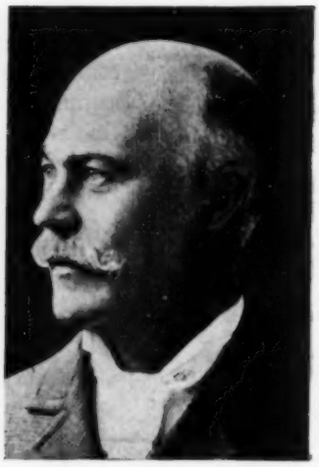

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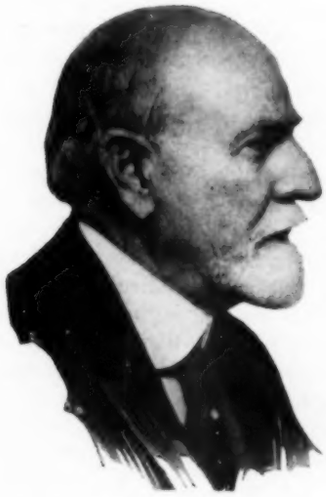

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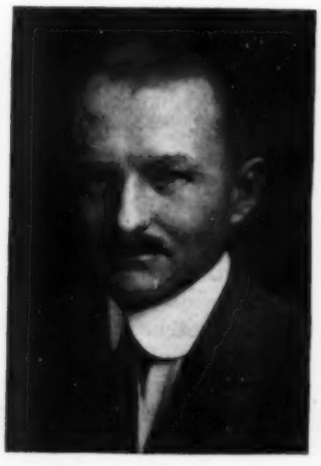


WALTER MCFADDIN
Middle Western Manager

Fifty Years of the AMERICAN MACHINIST

By JAMES H. McGRAW
President
McGraw-Hill Publishing Co., Inc.

"WITH the best facilities at our command we propose to make this the standard machinery newspaper of America, and to this end we shall direct all our efforts. We shall always act independently, not holding ourselves under the least obligation to give 'favorable notices' of anything under review, but rather to elicit the plain truth whether it be favorable or unfavorable."

FIFTY years ago, Jackson Bailey, first editor of the *American Machinist,* stated its policy in these words. The policy has been adhered to ever since but it has grown and developed with the times. Mr. Bailey's thought was of a newspaper that would reflect accurately the events in its field, without fear or favor, and he made of his thought a vital force that was greatly needed in the metal working industry of his day.

But, as industry forged ahead with giant strides, it was no longer sufficient for the business paper in the industrial field to serve as an accurate reflector of developments. Leadership was needed; leadership based on knowledge of the industry, high ideals of service and an ability to follow trends and forecast the future.

In its earlier days the *American Machinist* was most concerned with the problems incident to the conquest of materials. Little was known of the structure of metals and the methods of cutting and forming them were largely traditional. Many machinists were listed as subscribers but most of them were of the type that may be called the forerunners of the mechanical engineer.

Engines, boilers and the problems involved in the generation and use of steam were given a prominent place in the first issues, and rightly so, because each shop then generated its own power and the proprietor or manager had the supervision of that function to add to his other problems. Because the foundry of fifty years ago was more likely than not to be connected with the machine shop, foundry topics received frequent mention. The steam locomotive was given liberal space.

TODAY, with the rapid expansion of the metal working industry, specialization has forced steam power out of the shop, and consequently out of the pages of the *American Machinist.* The foundry, likewise, has long since reached the stage where it can be treated only incidentally in a paper that has had to include grinding, heat-treating, welding, material handling, press working and management in addition to machine design and metal cutting. The machinist of yesterday is the foreman, superintendent, engineer, manager of today. He must not only master materials, he must understand how to lead men, to co-ordinate their efforts, if he is to win success for his organization against the keenest, most intelligent competition ever known. Men of this type are the present readers of the *American Machinist* and for them it has changed its contents and its guise as they have changed. Management, design, production, the handling of materials and their heat treatment and finishing, are among the subjects with which the modern reader must be familiar and they take the leading place in the paper.

Comparison of the first issue with one from the current volume brings out clearly the advances in journalistic and typographic treatment that have been made. The wide use of the half-tone engraving that shows at a glance what a column of type might have difficulty in explaining is significant. Men work under higher pressure today, they have less time to read and therefore what they do read must be presented in the form easiest to comprehend in the brief time available.

THE *American Machinist* is proud of the part it has played in the formation of two great national bodies, the American Society of Mechanical Engineers and the Army Ordnance Association. Three years after the founding of the paper the idea of a national society of mechanical engineers was conceived. The first meeting of the proposers was held in the office of the *American Machinist* and would have ended in a disagreement had not the publisher, Horace B. Miller, tactfully invited the conferees to be his guests at dinner at the old Astor House. Mr. Miller's geniality, coupled with his fine choice of wines, made the dinner a memorable occasion and so mellowed his guests that they arranged for another meeting at the Stevens Institute of Technology in Hoboken a few days later. The second meeting resulted in the forming of the society that has grown to such splendid proportions. Lewis F. Lyne, Sr., then mechanical engineer of the staff of the *American Machinist,* had a large share in the drawing up of the constitution.

With the outbreak of the World War ordnance manufacturers suddenly took on a new and vastly greater significance. American plants were given large orders for guns, rifles, shells and other ordnance material. With few exceptions they had little experience in the work. Sensing the gravity of the situation *American Machinist* editors studied the methods that had been developed by the arsenals and published them in detail.

So well did they do their work that it met with general approbation which led to diplomatic exchanges that

opened the British munitions plants to the editors of the European edition, thus bringing the British methods to the attention of American manufacturers. The clearest proof that this job was well done is found in the decision of the British Admiralty to allot precious space on board ship for the sheets from the American edition that are sent over each week to be used in the European edition.

SOON after the entry of the United States into the conflict the editor-in-chief of the paper, John H. Van Deventer, was commandeered by the Ordnance Department. The rest of the staff redoubled their efforts to provide American munition makers with the technical information they needed. Fred H. Colvin spent more than four months in Washington and was of material assistance to the Ordnance Department in reconciling the opinions of the technical experts and the manufacturers.

This intimate contact with the industrial side of modern warfare led the *American Machinist* to support the post-war plan for industrial mobilization by every means in its power. Articles explaining the plan were secured from the Secretary of War, the Assistant Secretary, and the Chief of Ordnance. Meanwhile the suggestion to form an association of men who had seen service in the Ordnance Department and in munition manufacture began to take shape. The army officer assigned to carry out the organization details was given a desk in the *American Machinist* office and the publishers financed the embryo Army Ordnance Association in its first year.

With the rise of the scientific management tide the *American Machinist* stepped in to warn industry against the pretensions of pseudo efficiency engineers who were attempting, ill-prepared, to put the sound Taylor principles into practice. The most serious fault in the early days of scientific management was the ignoring of the very obvious fact that human beings cannot be treated like pig iron or machines.

The interest in the human element has been a distinguishing characteristic of the *American Machinist* since its beginning. In addition to the instance just given there is its record of support of the safety movement and of the workmen's compensation laws. The human, personal touch has been evident in the early writings of such philosophical engineers, or engineering philosophers, as Chordal, Prof. Sweet, W. Osborne and Tecumseh Swift and in the later work of John Godfrey, Glenn Quharity, Entropy, Dixie and Hi Sibley.

DURING the last year this tradition of human interest has been carried on by the dialogues of Al and Ed in the Foreman's Round Table, a feature that has been the most successful ever introduced by the *American Machinist*. Its success is significant of the modern trend. Today men are of primary importance, materials secondary. Men of skill, men that can be depended upon, are needed to take the responsibility for the operation of the complicated, expensive machines used in production.

Modernization of equipment has been a continuing slogan ever since the paper was founded. The first editors urged it editorially and described new machines and tools as they were introduced. Since the war redoubled emphasis has been put on the policy and many articles by industrial leaders who indorse it have been published. Within the last year an inventory of the equipment in metal working plants has been taken and the first actual figures showing how much of current equipment is more than ten years old have been published.

Jackson Bailey, the first editor, and his fearless policies have been mentioned. Equally vital to the progress of the young paper was the publishing vision of Horace B. Miller, the first proprietor, and Lycurgus D. Moore. They published a monthly magazine for three years and then changed to weekly publication which has been maintained ever since.

In 1896, John A. Hill bought the paper and injected his vigorous personality into its activities from that time until his death in 1916. A few months afterward negotiations to merge the interests of the Hill Publishing Company with those of the McGraw Publishing Company were completed and the *American Machinist* took its place as one of the most important papers in the group of McGraw-Hill business publications. Mason Britton, who had managed the paper for several years prior to Mr. Hill's death, continued as manager and has since become vice-president of the company.

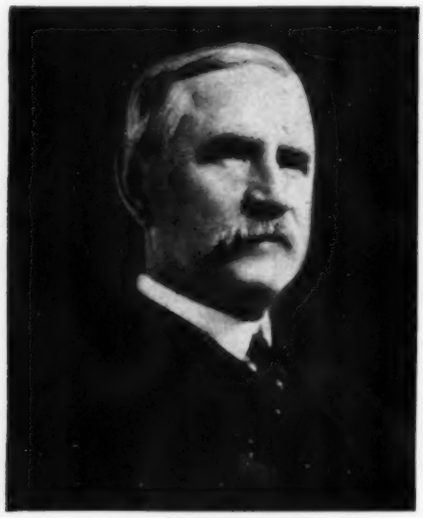
Jackson Bailey was succeeded by Frank F. Hemenway who carried on the editorial work until 1895 when Fred J. Miller, his associate, was made editor-in-chief. Mr. Miller served until 1907 when Frederick A. Halsey became his successor. Four years later Mr. Halsey retired because of ill health and was followed by Leon P. Alford. In 1917, John H. Van Deventer succeeded Mr. Alford and functioned until he was drafted into service by the Ordnance Department. Fred H. Colvin acted as editor until his return in 1918 and then took the title of chief field editor. Mr. Van Deventer resigned at the end of 1919 and was succeeded by Ethan Viall who had been managing editor. Mr. Viall served a year and in January, 1921, Mr. Colvin and Kenneth H. Condit were appointed joint editors. This arrangement is still in force, Mr. Condit carrying the executive responsibility and Mr. Colvin being free to travel widely to investigate the fields in which he has won a reputation.

MR. COLVIN joined the *American Machinist* in 1907 after many years of experience in the field of technical journalism. His first contribution to the paper was printed more than forty years ago. Mr. Condit came to the staff from the Army. Prior to his war service he had spent seven years in industry and on the engineering faculty of Princeton University. L. C. Morrow joined the staff in May, 1920, and was made managing editor at the beginning of 1921. His experience in industry and in ordnance work has been turned to good account.

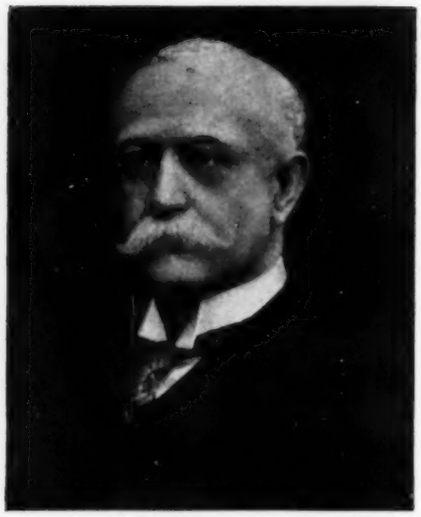
S. Ashton Hand, a member of the editorial staff for ten years, had his first contribution to the paper accepted more than forty years ago. Ellsworth Sheldon, New England editor, was also a contributor before he became an editor in 1918. The other members of the editorial staff, Henry V. Doyle, Jr., William E. Irish, Frank W. Curtis, Frank J. Oliver, Jr., and George S. Brady, are more recent acquisitions but none the less able.

The personnel of the editorial staff has naturally changed with the passing of the years, but the place of the *American Machinist* wherever metal working machinery is used is established. Built on a foundation of service to an industry, it has survived many a storm because of the soundness of that foundation. The ideal of service is still foremost in the minds of the editors and publishers and on it they base their hopes for the future.

JOSEPH FLATHER
First President



WILLIAM LODGE
1903-1905



E. M. WOODWARD
1905-1907

F. L. EBERHARDT
1907-1909

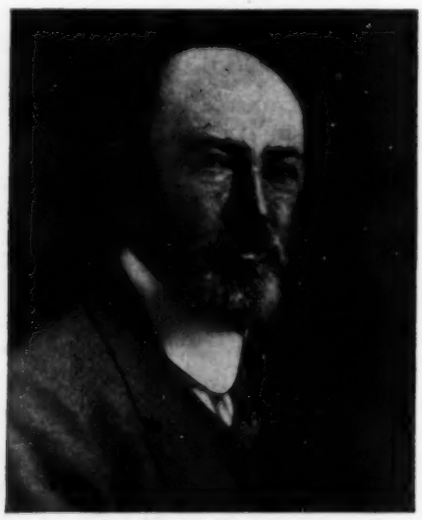
Twenty-Fifth Anniversary of the National Machine Tool Builders' Association

TWENTY-FIVE years ago, when the *American Machinist* was twenty-five years old, a small group of machine tool builders formed an association the objects of which were declared to be: "To promote the interests of the machine tool builders in the direction of good fellowship and the liberal discussion of subjects pertaining to the manufacture and sale of machine tools."

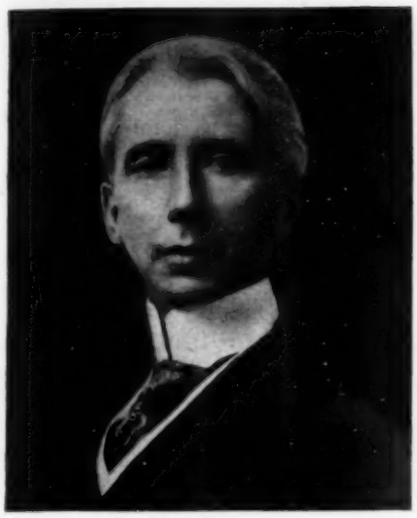
Good fellowship has been achieved and at the same time the association has been a factor in eliminating unfair competition. It has developed a spirit

FRED A. GEIER
1909-1911

E. P. BULLARD, JR.
1911-1913



W. A. VIALL
1913-1915



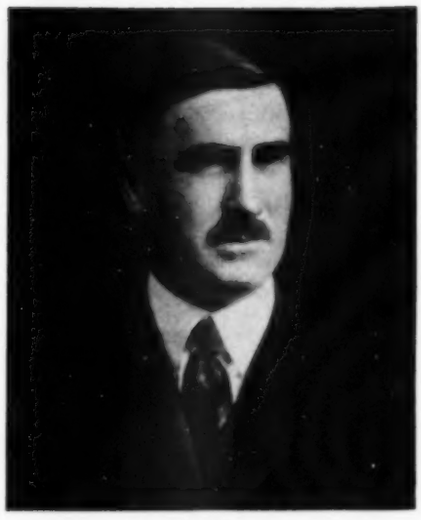
J. B. Doan
1915-1918

A. E. Newton
1918-1920

August H. Tuechter
1920-1922

of constructive co-operation that has done much for its members and has also been of real service to the users of machine tools.

From the very beginning attempts were made to standardize such details as spindle ends and electric motors. The association was among the first to draw up a uniform cost system and its code of ethics has been held up as a fine example for other trade associations to follow. Portraits of the fifteen men who have served as presidents of the National Machine Tool Builders' Association are shown in the order of their election.



E. J. Kearney
1922-1923

Ralph E. Flanders
1923-1924

O. B. Iles
1924-1925

H. M. Lucas
1925-1926

James E. Gleason
1926-1927

Machine Shop Practice Developments in Fifty Years

By JAMES E. GLEASON
President
National Machine Tool Builders' Association

TWENTY-FIVE years ago the *American Machinist* published an anniversary issue in which the marvelous advances of the machine tool industry were described in an editorial. According to this editorial there were only about twelve plants building machine tools in 1877. They employed 2,000 men and had about $2,000,000 invested in the business. In 1902, there were 150 plants employing 25,000 men and showing investments of $25,000,000. Today, twenty-five years later, there are over 300 plants and they employ twice as many men. At the peak of production, near the end of the World War, the value of machine tools produced in a year was estimated at $500,000,000. Something of what the machine tool has contributed to shop practice will be found in the articles and pictures that take up the next thirty pages. It is sufficient to say here that there is no single group in industry that has worked more devotedly, or with less self-interest, for the good of the community than has this group. Most of the men in it have given more thought to the engineering problems they had to solve than to the direct financial reward that they would receive. Consequently they have a good deal of fame but small fortunes. This has resulted to the advantage of their customers who purchased continually improved machines at comparatively low prices. The users of machine tools have been led to expect a very high return on their investment. In some cases 400 per cent has been recorded and 100 per cent is quite common.

I have dwelt upon the twenty-five year period because it seems to delimit an epoch. In 1877, the industry had reached a point in its development that justified the establishment of a paper to devote itself to the problems peculiar to the industry. In 1902, further growth made it desirable to form an association of manufacturers and the National Machine Tool Builders' Association came into existence. The association, of course, is devoted primarily to the interests of machine tool builders while the *American Machinist* serves the far greater number of machine tool users as well.

IN THE last analysis the machine tool builder is most concerned with his success as a craftsman, as a builder of machines that will make easier the work of others.

Professor Sweet, famous as an engineer and revered as a man, wrote in the twenty-fifth anniversary number of the *American Machinist*:

"If the machine tool builder of today could fully grasp the revolution that is to come over the trade within the next quarter of a century it would be a revelation to him, and yet a glimmer of what is to be can be dimly seen. While all the standard machines will still be made and used, they will be built primarily to do work rather than to suit the convenience of the operator, and so improved that they will still be easier for the operator to handle. Instead of the designers studying to find out where they can take out a pound of iron and not have the machine weakened, they will study to find where they can put in another hundred and make it pay in the more and better work the machine will do. They will revolutionize the drive and feed mechanisms so the workmen can get the best of both without exertion, and they must to a large extent make the machines self-contained and true, wherever they may be set and on whatever they set, for many of the machines are to go to the work and not the work to the machines. Great industries permit of great quantities. Special machines will be more largely employed, because then there will be pieces enough of one kind to keep one or more machines employed at a few operations or a single one, and there will be far less idle capital in long machines doing short work and large ones doing small work. When there is enough of a kind the automatic machine will do the work, and inconsistent demands from inconsiderate workmen may in many cases develop automatic machines before even economy justifies their being brought into existence. None but the builder of national reputation can make bold departures and sell the machines. The average maker forgets that the way the other man made his reputation was exactly by these bold departures, superior workmanship and high prices."

THE extent to which his prophecies have been realized is a tribute both to the vision of Professor Sweet and to the initiative and ability of the machine tool builders.

But even the foresight of a Sweet could not predict many of the improvements that have been made in machine tools. Adequate lubrication has finally been provided for in many of the machines, lubrication that is independent of the memory of the operator, to a large extent. Power applications have been developed to a point undreamed of twenty-five years ago. Convenience of operation has released the machinist from physical exertion so that his energy can be devoted to the control of power-driven mechanisms.

Standardization has been advocated by every forward-looking man connected with the industry but it has been slow in gaining favor. Recent developments, however, are distinctly encouraging. Research will come into its own in time but it has made little progress as yet.

Professor Sweet is gone, but if he were still with us I wonder if he would venture a prediction as to the directions of development in the shop during the next twenty-five or fifty years. If our present accelerating rate of progress continues, where we shall be at the end of another generation is beyond our comprehension.

Turning, Fifty Years Ago and at Present

AT THE time the *American Machinist* came into being, nearly all cylindrical work was produced on lathes. The vertical boring mill was in existence, it is true, but it was used only for very large work. However, not all the lathe work was done on engine lathes, since the hand lathe was still in use in many shops. Such lathes were made as large as 24-in. swing. The larger sizes were back geared and had wooden shears plated with flat bars of iron. While the slide rest was generally a part of their equipment, much of the work was done with hand tools, of which the hook tool played an important part.

Threads were cut with a hand chaser, the use of which required considerable skill. Everything depended upon the first pass of the chaser. If it was not moved in proper relation to the revolutions of the work, the lead would be incorrect. If its motion was not constant an uneven or "drunken" thread would result. The apprentice boy who could not cut good threads with a hand chaser in his third year in the shop was not thought to be of the material of which first-class mechanics are made.

Fifty years ago, the matter of centering work was not considered to have much bearing upon the roundness of the product. The average lathe centers had an included angle of about 90 deg. and the points were not sharp. Much of the work was not center drilled and countersunk. Instead, a center punch of approximately the same angle as that of the lathe centers was driven into it with a hammer. In the case of heavy work, the center punch would be held in a pair of tongs by the lathe man, while his helper played "ten-count-ten" on it with a sledge. Of course such practices did not obtain in shops building machine tools and other accurate work, but then such shops were in the minority.

FEW centering machines were in use fifty years ago. The location for centers was found by the use of hermaphrodite calipers; a pair of "morphidites" as they were called, could be found in every lathe-hand's kit, though the center square had found its way into the hands of some first-class workmen. When centers were countersunk, the work was revolved against the old "square center," held in the tailstock, using a forked rest in the toolpost. The tapered holes in lathe spindles were not often true, so that live centers, when taken out, had to be replaced in the same position they occupied before removal. To this end, after the live center had been trued up in place, it was common practice to put a center-punch mark on the end of the spindle nose and one on the center, so that whenever the center was taken out it could be replaced in its original position by bringing the punch marks fair with each other.

Lathe chucks were of two types, independent and universal. The combination chuck which could be changed from independent to universal, or vice versa, by the movement of a small button; wrenchless chucks; and chucks operated by fluids under pressure, or by compressed air, were not known fifty years ago. However, two-jawed box chucks of practically the same type of those in present-day use, were to be found in nearly all shops where brass work was a specialty.

MUCH chucked work was bored in the lathe by the use of a flat drill held in a slotted rest in the toolpost, and guided by the tail center. Holes made by this method had to be finished either by boring with a single-pointed tool, or by reaming. But all holes were not made to standard sizes and therefore could not be reamed with solid reamers. Consequently, one of the most useful tools of fifty years ago was the expansion reamer, not the tool of that name as we know it today, but a reamer that could be expanded as much as $\frac{1}{8}$ or $\frac{3}{16}$ in. above its nominal size. And reamers in general have passed through a period of great refinement, due principally to meeting the requirements of the automotive industry. We now have reamers of several types, both single and in tandem, that can be depended upon to produce holes within 0.00025 in. of the size called for.

When the lathe hand of fifty years ago had bored and reamed a hole in work that had to be turned, did he mount it on a nice hardened and ground mandrel? He did not, for the reason that such tools were not available. Mandrels of that time were miscellaneous pieces of round iron or steel culled from the scrap pile. They were turned far enough in length to hold the work. Thus mandrels could be seen having spots of various diameters occupying their entire length. When they reached this condition, they were put to one side to be turned to fit holes of the next smaller size.

Many of the accessories of the lathe hand of fifty years ago would seem crude and unusable by the lathe hand of today. And yet the lathe hand of the earlier time did good work. He knew nothing of tolerances and limits, he did not work with micrometers and gages—his whole measuring outfit consisted of a steel scale and inside and outside calipers. His work was not round, as we know round work today—he had no way to make it so, but his running, driving and shrinking fits were made with a certainty that would put to shame the average machinist of today, were he deprived of the use of "mikes" and gages.

The lathe hand of fifty years ago was of necessity possessed of much skill and resourcefulness, and he had

to know his individual lathe thoroughly, for every lathe had tricks of its own.

Practically all lathe work was finished by the use of files, scrapers and abrasive cloth. While cylindrical grinders were in use in such shops as made sewing machines, they were only for small work that had to be finished after it had been hardened. The machines carried small, narrow wheels, rarely over 10 in. in diameter and of ½-in. face. The wheels were run dry. No one at that time dreamed that the grinder would ever take the place of files and abrasive cloth for finishing lathe work, or that work turned with a very coarse feed would be considered finished as far as the lathe part was concerned.

Change gears on screw-cutting lathes were exactly what their name implied, since one or more gears had to be removed and replaced by others whenever threads of different pitches were to be cut. Though Bancroft & Sellers had patented a quick-change gear as early as 1854, it never came into general use. Many other attempts were made to apply quick-change gears to lathes, but it was not until 1892 that one of the first commercially successful devices of the kind was brought out by Wendell P. Norton and incorporated in the Hendey-Norton lathe. While speaking of gears, it may be in order to state that the Ames Manufacturing Co., Chicopee, Mass., made lathes having helical back gears, as early as 1874. Moreover, the angles of helix were in opposed directions on the gears at opposite ends of the headstock in order to eliminate end thrust.

On many of the engine lathes the lead screws were not splined to carry a gear or worm to actuate the turning feed. A separate feed rod driven by a narrow belt at slow speed was used instead, and the feed lacked the power for fast cutting. Where what were then called heavy cuts were taken, water was allowed to drip or trickle from a small can on to the tool, but coolant flooding the tools and the work was not thought of. Nor would it have been possible without a change in the construction of the machine either to catch the used coolant and return it to a reservoir from whence it could be used again, or to prevent it from running over the shop floor.

THE general method of turning tapers was either to set over the tailstock or else to use a slide rest. In boring taper holes, except on large lathes equipped with a compound rest, the slide rest was again resorted to, though a skillful workman could rough bore a taper hole by operating the cross-feed by hand while the carriage was fed longitudinally by power. Such holes were of necessity finished by taper reamers of some sort. The late John Richards used to tell of a boy who bored taper holes by turning the cross-feed handle a specific number of increments to the time of a certain tune he whistled while the longitudinal feed carried the tool along.

Facing was done by operating the cross-feed by hand, very few lathes, except the larger ones, being equipped with power cross-feed and none having power feed applied to the compound rest.

It is true that makers of brass goods had the Fox lathe with its setover turret, its chasing bar for threads and its device for turning tapers. Also hand screw machines were in use for making screws and other work of small diameter and short length. That the hand screw machine would eventually be made automatic in its movements was but a natural sequence, but that the turret principle would ever be adapted to machines handling bar work of any considerable size and length, or that such machines would supplant the lathe as a manufacturing machine for many kinds of work, was not thought of until Hartness brought out the flat turret lathe. This machine was a revelation to manufacturers and it paved the way for a number of other turret lathes of the hand and semi-automatic type. The development of the engine lathe has resulted in the production of manufacturing machines built to handle short work, or work of small diameter.

FIFTY years ago, turning speeds were from 15 to 25 ft. per min., and feeds were from $\frac{1}{32}$ to $\frac{1}{8}$ in. per revolution. Any man who would have predicted that steel could be turned at 75 ft. per min. and over would have been deemed a candidate for the lunatic asylum. Such speeds were made possible only by the introduction of high-speed steel. Yet we had high-speed steel more than fifty years ago, only we did not know it. Mushet steel (a steel containing tungsten and manganese) was used for machining hard material, but no one thought of using it on regular work at increased speed. While the steel would have stood the punishment of the increased speed, the machines were not powerful enough to stand the strain. Nor did the modern high-speed steel come into its own until the machines were made heavier and were equipped with more powerful drives and feeds. When Taylor and White brought out high-speed steel, they refused to license its use to shops that would not agree to put in equipment powerful enough to reap the benefits from its use. Unless this were done, they well knew the new steel would get a "black eye" and that their business would suffer in consequence. That the introduction of high-speed steel was responsible for the development of the geared-head lathe no one will deny.

The vertical boring mill has been developed into a turning as well as a boring machine. Today we have vertical boring machines doing much of the work that was formerly done in the lathe, and doing it faster and better. Some such machines are equipped with turret heads and with side heads that can be operated both horizontally and vertically. They are simply lathes of large swing and short length, stood on end. In fact they are known as vertical lathes.

Grouped in multiple, stood on end, carrying work-holding devices and a full equipment of tools, the lathe has been developed into a highly specialized machine such as the Bullard "Mult-Au-Matic." These machines are tooled to finish pieces in a certain number of operations, the work being indexed from one station (or lathe) to another, each of which is equipped with tools that are set for but one operation, and with devices for holding and feeding them.

Truly the machinist used to the simple, belt-driven engine lathe of fifty years ago, if called upon to operate one of the so-called lathes in the manufacturing plant of today, would be confronted by a machine he would hardly recognize as a lathe, and would be so bewildered by the array of levers and controls required for its operation that he would be at a loss to know where to begin.

Twist Drills, Drill Chucks and Drilling Machines

BUT a few years before the *American Machinist* made its initial bow to the machine shops of America, a most important contribution had been made to the metal working industry in the shape of the twist drill, the tool to which is generally accorded the distinction of being the most efficient cutting medium in proportion to its size and weight of any that is available to the machinery worker.

History does not record when or by whom the first one was made, but to Stephen A. Morse is usually given the credit for being the first to perceive the commercial possibilities of the twist drill and the courage to engage in its manufacture, for in the year 1861 he started a little shop in East Bridgewater, Mass., to produce drills for the market.

How he made the flutes in his first drills we do not know, but by 1864 or earlier he had devised a special milling machine to cut the "increase twist" and a cutter to make the shape of flute necessary to produce the "straight lip," both of which features are covered in a patent granted to him on April 7, 1863. Though many improvements have been introduced since that time, few of them have materially affected the structure of the drill, and, to quote a man who has long been identified with the twist drill business and who has participated in many attempts to increase the life or enhance the cutting qualities of the tool, "we must take off our hats to Stephen Morse, who made it right the first time."

Having become established as a commercial necessity the tool attracted the attention of other inventors, some of whose ideas and devices have worked marked advances —particularly in machinery and methods of manufacture—while others were trivial and non-essential. Though the modern drill is much stronger and more efficient than its early counterpart, such changes as have been made are not easily discernible in the finished tool, and a drill of 1927 when compared with one of 1877 would present no marked difference in appearance.

IMPROVEMENTS were first effected by gradually introduced refinements in methods of manufacture. Grinding machinery helped to produce drills more accurately; clearances that once were filed by hand are now made far more rapidly and infinitely more uniform by automatic machines; and improvements in steels have rendered them more resistant to breakage. The greatest single factor was the advent of high-speed steel, which, in connection with modern scientific methods of heat-treating, has far more than doubled the efficiency of twist drills.

Though all of the early drills were made by milling the flutes from the solid stock and the majority—in numbers, at least—are still made in the same way, the forging process has become more and more a factor, especially in the production of the larger sizes and of high-speed steel drills, upon which the saving in material is no inconsiderable item. Several methods of forging are regularly employed.

Electric welding has contributed its share to twist drill manufacture by making it feasible to weld shanks of carbon steel to the high-speed steel drills. Blacksmith's drills, bit-stock drills, and sets of drills that are made in a range of sizes with uniform shanks, also have their shanks welded on, either by the electric or other process.

THE most noticeable change in the structure of the drill is the "constant angle" of helix, introduced about 1892 to overcome the objectionable feature of the constantly changing rake angle at the cutting edge as the drill is shortened by regrinding. The majority of large drills are now made with constant angle of helix, while the smaller ones retain the feature of the increase twist. Different pitches, or angles of helix, have been introducd in order to provide drills to cut different materials efficiently.

Along in the affluent days of the bicycle industry the demand for drills to make deep holes led to the introduction of the oil-tube drills, which were made in several ways. One method was to mill an open groove along each land and, after the drill was otherwise finished, solder a pair of brass tubes in the grooves. Another method was to profile a dovetail along the open top of each groove and, after hardening the drill, peen in strips of sheet steel to cover them. When such a drill has been reground on diameter and clearance the joints are invisible.

Probably the most widely practiced method of making oil ducts in a drill is to drill a pair of holes through the blank parallel with its axis, twist the blank backward while heated to forging temperature, and mill the flutes between the now helical ducts in a later operation. Quite small drills have been produced in this way by starting with a comparatively large blank, filling the holes with siliceous material and plugging them, twisting the blank and then reducing it to the desired diameter by the process of rolling. The material in the ducts—essentially molten glass—prevents them from being distorted by the rolls.

It is strange that only in recent years has there been general recognition of the importance of correct drill sharpening. Satisfactory grinders for sharpening drills have long been available but they have not been used to anywhere near the extent they should be. The demands of high production are forcing their adoption.

There were drill chucks on the market before twist drills were made, but they were rather crude and cumbersome in comparison with present-day tools of their class. Early chucks, usually with two opposed jaws operated by a wrench, were supplemented by those of the sleeve type in which three tapered jaws are closed concentrically upon the drill by turning a threaded sleeve, the bore of which is tapered to correspond to the taper on the backs of the jaws. The gripping power of such chucks when closed by hand is small and is augmented by the use of spanners. Furthermore, it usually required about three hands to manipulate them: one hand to set in the drill, one to turn the sleeve, and a third to hold the spindle of the machine against backward rotation. The same type of chuck with a toothed sleeve and pinion wrench is now the more generally used.

Where small drills are to be changed frequently, as on production jig-drilling, the automatic, or spring-actuated, chuck is often used. This chuck is operated to release the drill by grasping the revolving sleeve with the hand and applying sufficient friction to overcome the pull of the spring, when the drill will drop out. Another drill is set into the chuck and the sleeve released, when the spring will cause the jaws to close upon it. The jaws of this type of chuck are so made as to grip more strongly as the resistance to the drill increases.

As the sizes of drills increased the makers saw the necessity for a means other than the drill chuck to hold them, and they applied the principle of the taper shank. The grip of the taper alone being insufficient to drive the drill to capacity, the flat tang and corresponding keyed collet were devised, and so effective and convenient did this method prove that the system of taper shanks adopted by Morse in the early days of drill making is now almost universally applied to drills and drilling machines. Other shanks used in some specific instances are the Sellers keyed shank with its square-sectioned key, and the Graham shank—sometimes called the Westinghouse shank—with two wide grooves, or flutes, along each side parallel with the axis of the drill.

Another driving device that has come into extended use in connection with jig-drilling is the slip-collet. This consists of a master-sleeve to go into the spindle of the machine and any number of mating parts, each to be secured to a drill by taper-shank, setscrew or other means. With this device the operator can change drills without stopping the machine. It serves the same purpose with medium-sized and large drills as the automatic chuck with smaller ones.

CRUDE in construction and deficient in power as we would now consider them, the drilling machines of fifty years ago were more than a match for such drills as could be obtained for them. Rotative speeds were slow, and the rate at which a drill would penetrate the work was well within the operator's ability to keep it cutting to the limit of its capacity by means of the simple screw and rack-and-pinion feeds then universally applied.

With increasing powers of resistance of the drills came the demand for more powerful and accurate machines to drive and guide them. Machines have become heavier, speeds have increased, more power has been applied, and power feeds have become essential to all classes of drilling machines. Where once an operator's chief concern was to refrain from driving a drill to the breaking point, he now finds it difficult to overload it.

Sensitive drill presses grew out of the increasing use of small drills; being so named because of the fact that the method of feeding by a hand lever enabled the operator to sense the resistance of the material to the drill and govern the rate of feed accordingly. They are life-savers to very small drills.

Radial drilling machines came rapidly to the front to take the place of the ratchet and "old man" on the job of drilling holes in castings too large and heavy to be moved easily. From the simple radial, capable of drilling holes only parallel with its column, has developed the versatile machine of today, with powerful drives, almost universal angle of application and with practically all movements of adjustment handled by power.

Portable machines, small enough to be carried in the hand and applied manually, can be used in any place where an air-pressure line or electric outlet is available. Small radials and semi-radials are mounted on trucks to be wheeled about the shop or yard for work upon parts that cannot readily be moved to the machine.

AS MASS production became the order of the day and jig-drilling was generally introduced, the single spindle machines gave way to multi-spindle machines and to single-drive, multiple-head machines containing any number of spindles that are capable of adjustment to suit the location of holes on any job. Finally came the "way" drilling machines, which are really special machines designed to drill one part. These machines may have any number of spindles, lying in any plane, rotating at different speeds and in different directions, to complete the job in one cycle.

The screw machine, designed first to meet the demands of makers of guns, sewing machines, etc., for accurate small screws, developed into a line of general production machines capable of turning out almost any part not too large to be completed before cutting it off the bar, and widened the market for twist drills.

Production problems in the matter of drilling the greatest possible number of holes in a given time have brought about many improvements in the details of drilling machinery. Anti-friction bearings, first appearing as thrust bearings under the quill, are now applied to nearly all rotating parts. Where rotative speeds up to 500 r.p.m. were considered fast enough for even the smallest drills, there are now machines on the market with specified speeds of ten thousand.

But a few years ago no one thought of putting oil upon a drill when drilling cast iron, brass, or similar materials, and if concession was made in the case of wrought iron and steel it was because the drill squealed, and the lubricant was then grudgingly applied with a hand oil-can. Now, standard drilling machines of all kinds are amply splash-guarded, provided with circulating pumps, and in many cases with self-contained reservoirs.

Perhaps the most compelling evidence of the increased production capacity of drills and drilling machinery is to be found in the amount of power applied to them. Where in the old days we would find a single-spindle machine of 1-in. nominal capacity driven by a 2½-, or at most a 3-in. single belt running over a pair of cone pulleys without back gears, we may now see them with double belts and geared drives, often absorbing the energy of a 10,- or even 20-hp. electric motor.

Five Decades of Progress in Planing

THE planer of fifty years ago was far from the production machine that it is today, and for very good reasons. It did not have the strength, weight and speed of the planer of today. Neither had it the conveniences. Very few of the planers of fifty years ago, except the larger ones, were placed on foundations, and those that were so placed had no provision for keeping them level. It was thought that once leveled and grouted to their foundations, they would always remain level. Today we know differently. Not only do we provide massive concrete foundations for them but we place screw-operated wedges at intervals between them and their foundations. And these wedges are used from time to time to relevel the machines when tests made periodically demand it. Nor is a carpenter's level used for testing them. The best of precision levels is considered none too good for the job.

Usually planers had but one head on the cross-rail and even the heaviest planers equipped with side heads on the uprights were rare.

The open side planer was little but a dream in the mind of its inventor. He was undecided as to how such a machine would be received, and many to whom he showed the drawings were skeptical as to its success.

Cross-rails were raised and lowered by hand power, and on large machines they were raised only when the work in hand would not pass under them and were lowered only when the tool could not be made to reach the work by any other means.

Cutting speeds rarely exceeded 15 ft. per min., and the return speed of the table was about 20 ft. Planer tables traveling at 30 to 40 ft. per min. under cut, and slammed back at from 75 to 100 ft. per min., would have been deemed impossible.

FINISHING was done with light cuts and very fine feeds, wearing the edge from the tool before it had traveled far. It is true that William Sellers & Co. were finishing work with broad, flat tools at feeds of from ⅛ to ¾ in. at each stroke. But this practice did not obtain in many shops, for the reason that the majority of planers would not stand such feeds without chattering, and few but railroad shops could afford the price of the Sellers heavy, worm-driven planer.

Speaking of the worm drive brings to mind a test of the first worm-driven planer built by the Niles Tool Works—not a planer driven by a worm meshing into the rack (that was patented), but one in which a worm and wormwheel were used to reduce the speed between the driving and driven members. The planer stood at the rear end of the shop, the end of the table just clearing the brick wall when run back to its fullest extent. A "cob house" of timbers was built up against the wall to nearly the height of the planer table. On the top of all was placed a short piece of heavy timber, "end on" between the planer table and the wall. The planer was started, and much to the surprise of all present, the block, instead of stopping the planer table, was driven through the wall, taking with it half a ton or so of bricks. The consensus of opinion was that the planer would pull any cut demanded of it.

IN THE planers of fifty years ago there were no differential belt shifters. Instead the tight and loose pulleys were of different widths, the tight pulleys being the narrower. When the belts were shifted, the belt on the tight pulley would reach its mating loose pulley at about the same time the other belt engaged its tight pulley. And how the belts would shriek as reversal took place.

When the shifting apparatus became worn, it was not uncommon for both belts to be partially engaged with both tight pulleys at the same time. Then the table would "see-saw" back and forth a few inches, undecided as to which way it would eventually go as the belts fought for their grip. At such times the shrieking of the belts was almost deafening. To obviate trouble of this kind, some planers had a tumbling shaft weighted with a heavy ball, and so arranged that the ball would be past the center before the shifting was completed. The falling weight of the ball would move the shifter to its fullest extent. Since this device was of necessity placed close to the floor and near to the operator's position, lucky was the operator whose foot was not at some time caught between the ball and the floor.

The differential belt shifter did not entirely eliminate the shrieking of the belts, for it was yet to be discovered that the overcoming of the inertia of the heavy pulleys running at high speed was a major contributor to the trouble. Realizing this, one builder put aluminum driving pulleys on his planers. Not only did this procedure eliminate most of the noise, but it decreased the power necessary to operate the machines and actually increased the number of strokes per minute.

Few of the planers of fifty years ago, except the larger ones, had automatic down and angular feeds, so that side facing required the constant attention of the operator. Micrometer collars on feed screws had not been thought of, and such a matter as accurate spacing of the heads on the rails by means of indicators and end measures, had not entered the minds of either the designers or the users.

One type of planer, the Richards, seems to have fallen into the discard, and for no apparent reason, for it was an excellent tool. Its appearance was much the

same as that of a very long traveling-head shaper. It had two tables, or knees, both of which were adjustable for height, and for position lengthwise of the bed. Unlike the shaper, however, the saddle was traversed lengthwise of the bed for the cut, while what would have been the ram in a shaper, was the cross-slide. The tool head was, of course, set on the cross-slide at an angle of 90 deg. from its usual position on the ram of a shaper. Such planers were used for comparatively long and narrow work, for which they were very convenient. Work that was higher or thicker at one end than at the other could be set level by changing the relative heights of the knees, thus doing away with a lot of blocking.

Such matters as T-slots and holes for stops were different in each make of planer, so that where planers of different makes were in use in the same shop, the bolts used for holding down the work were not interchangeable from one planer to another. The quantity of bolts, blocks, straps, clamps, stops, hold downs, parallels and other paraphernalia, required in the operation of the planer of fifty years ago, occupied an enormous amount of room and in some cases almost equaled in weight that of the planer itself, for the planer was strictly a jobbing machine and had to take care of any kind of work that was brought to it. In many cases work was so tightly clamped as to spring the table. No one appears to have known that putting paper between the work and the table would eliminate the necessity for such tight clamping.

While the planer of today operates upon the same principles as did its prototype of half a century ago, the changes and improvements have made of it almost another breed. It is many times heavier and stronger and it is equipped with all sorts of conveniences for its operations, such as quick power-traverse of the heads on the cross-rail and those on the uprights; power for raising and lowering the rails; selective feeds that can be operated by a touch of the finger; controls that can be operated from both sides; automatic devices for clamping the cross-rail in position; and last but not least, the reversing motor drive. Tables of box form give added rigidity without greatly increasing the weight. And as to the power absorbed in cutting—a planer of a given size requires from eight to ten times the power required by its elder brother. But this does not mean that any of this extra power is being wasted. Far from it. It means that the modern planer is doing an enormously greater amount of work.

THE methods of lubricating the V's have been vastly improved, so that they are automatically oiled by rollers set at intervals lengthwise of the bed, and dipping into pockets or small reservoirs filled with oil. In the case of very large planers, oil is forced between the V's of the bed and those of the table by a pump, so that the table floats on a continuous film of oil. Means are provided for returning the surplus oil to a central reservoir.

While high-speed steel has greatly increased the output of the planer, it has not shown up to the same advantage as in the lathe, except on very heavy work. And the reasons are not hard to find. In the lathe, not only is the work symmetrical, but metal is being removed from its entire surface and the strains so set up are practically equalized. Also the heat generated by the high cutting speed expands the work equally in all directions. In the planer the work is generally unsymmetrical and the metal is removed from but a part of its surface, setting up unequal strains and springing the work. Also the heat generated by the high cutting speed distorts the work so that the finishing cut cannot be taken until after it has cooled. In many cases the time lost in waiting for the work to cool more than counterbalances the advantages gained in cutting at high speed.

And the practice of handling heavy planing work has undergone many changes. Now, planers are set on heavy floor plates that are planed to a true surface and provided with T-slots at intervals in both directions. Work too high or wide to pass through the housings can be machined in two different ways. In one way the work can be mounted on the planer table and the stroke so adjusted that the planer will reverse before the work strikes the uprights. On the floor plate is fastened a heavy column that is practically a cross-rail set on end. This column carries a planer saddle with its clapper box and toolholder. A cut can be taken on the side of the work facing the column. In the other way, the work is mounted on the floor plate, while the tool is carried in a head attached to an angle plate, the rig being mounted on the planer table. Either of these methods renders the planer, as Chordal says, "to all intents and purposes, as good as a planer that will take in a cathedral."

WHILE on the subject of the planer, the shaper must not be forgotten. It, too, has passed through many changes and refinements. It has not only been made heavier, larger, stronger and more accurate, but more convenient for the operator. Shapers are now made having a stroke as long as 36 in., and are capable of handling much work that would formerly have had to be done on planers. The shaper of fifty years ago had to be at rest when the length of the stroke and the position of the ram were changed. In the shaper of today those adjustments can be made while the machine is in motion. Lubricating systems that are almost automatic have been added, so that it is no longer necessary for the operator to use a squirt can in oil holes, some of which were in out-of-the-way places in the earlier machines.

Beside the improvements in the machine itself, it has paved the way for the development of other machines, such as the draw-cut shaper, a machine of versatile uses, particularly adapted for railroad- and marine-engine work. The old-time traveling-head shaper with its two knees, is still with us, and it is a very useful tool. Long work can be supported and leveled upon its knees while cuts are taken at or near the ends. Curiously enough, the traveling-head shaper was one of the first machines capable of being converted into a station-type machine, for work can be set up on one knee while the tool is operating on work held on the other. Had its capabilities in this respect been recognized at an earlier time, it might have been in more general use today. At any rate it might have blazed the trail toward an earlier development of the station-type machine.

And the slotter, which is practically a shaper stood on end, has come in for its share of improvement and increase of both ruggedness and size. In addition to the heavy-duty machine of the present, we also have machines of the same type, though of comparatively small size, accurate enough for toolroom use.

Development of Milling Since the Year 1877

THE milling machine is a development of the rotary gear cutter, which was used in Europe as early as the sixteenth century. In its original form, the milling cutter was merely a rotary file and it was still such when the earliest milling machine was built in the United States by Eli Whitney, of cotton-gin fame, in 1818. Few developments took place until the early fifties when E. K. Root built a machine with a 3-step cone pulley and an overarm support for the arbor. About the same time (1854), Francis A. Pratt designed a manufacturing-type machine at the Phoenix Works of the Geo. S. Lincoln Co. in Hartford. It embodied screw feed to the table, and the spindle journals were carried in boxes that slid in upright guides. It was driven by a cone pulley and had one gear step. Later an outboard support was added to the spindle, thus making what we know as the Lincoln type machine. Crude as it appears it has survived exactly the same in principle of design today. A few refinements have been added, of course, and it is now more sturdily proportioned to withstand modern loads and speeds.

IN 1862, Joseph R. Brown designed the universal milling machine to cut spiral flutes in twist trills used in the manufacture of gun nipples. The indexing spiral head used has come down to us today little changed. A little later Brown developed the form cutter, which could be sharpened without changing its contour.

When the *American Machinist* first appeared, milling was well established as a manufacturing process. There were about seven companies building milling machines, all but one of which survive today, two under their original names.

One company built a Lincoln machine that was fast developing into a planer type as we know it today. The outboard bearing was carried in a cross-bar that also incorporated the two inboard bearings, the whole sliding on the outside of guides. The bed also resembled a planer bed more than previous models.

One of the first true planer-type millers was built by the Brainard Milling Machine Co. in 1884. It was massive in construction and was intended for railroad work. The table was 7 ft. long and could be fed its own length and had rapid traverse by power. Where a few years before an arbor 1 in. in diameter was standard, this machine had one 2½ in. in diameter. From this point on, steady increases were made in the capacity of the planer-type machine until in 1907 a machine 20x10x8 ft. was built for one of the large manufacturers of electrical equipment. In 1888 there appeared a planer miller with a bed 10 ft. long for finishing beds of lathes. Tables 16 ft. long were seen three years later. Improvements followed: Heavier construction was used, side heads were added, rapid power traverse was applied to the heads and the rail, and with these improvements and those that took place simultaneously in cutters, particularly of the inserted-tooth face-mill type, higher feeds and greater production were gradually obtained.

As a development of the planer-type miller with its vertical spindle carried on a rail, there appeared in England in 1899 a machine with a revolving table and a spiral cutter. A year later several American companies simultaneously put machines of this type on the market. Developments that followed were largely of size. Rotary or continuous milling machines, although of the same family, did not come into vogue until special fixtures were introduced by the automotive builders in 1910. Several companies then built machines to meet this demand.

In principle of design, little has been changed in the column- and knee-type machine in the past fifty years. Radical improvements have been made in the drive, the feed, and the rigidity of both the spindle and the table supports, however.

Shortly after the *American Machinist* appeared the Buckeye Iron & Brass Works of Dayton, Ohio, introduced the Krutzsch machine of foreign design that was far in advance of contemporary machines. It was a column-and-knee type and could handle a piece weighing a ton. The table could be raised 19 in., the cross-feed was 26 in. and the parallel feed, 14 in. Twelve spindle speeds were available through a cone pulley and back gears, and in the base was a reservoir for coolant supplied to the cutters by means of a rotary pump.

THE Holz miller brought out a few years later featured among other things, centralized control and, for the first time, counterclockwise rotation of the spindle so that standard drills, reamers and boring tools could be used. Between then and 1900, few notable changes took place. The telescoping screw for elevating the knee was introduced, thus eliminating the bothersome hole in the floor, previously necessary. A larger number of speeds became available, eighteen in one case, and feeds were controlled automatically by means of trips. As heavier cuts were being taken machines were being built "to secure great strength and rigidity" as one manufacturer put it. During this period, a magnetic chuck also was first placed on a miller.

Rapid advances were made in the beginning of this century. Heavier feeds forced the adoption of geared instead of belted feeds, the first machines so equipped appearing at the Pan American Exposition. A little later, a "radical departure" was introduced. It was an

all-geared-head machine driven by a constant-speed pulley and had pads on the base for use with motor drive. Almost simultaneously another company put out a machine driven by a variable-speed d.c. motor mounted on a side extension of the base. It drove through a chain and was controlled by a friction clutch. Later the motor was placed on the head and thus we have the first built-in type. These drives were shortly standardized.

In the meantime, much attention was being given to indexing heads, particularly of the differential type, and many of the designs produced then survive today without major changes.

OTHER companies followed with motor-driven models and constant-speed pulleys, and by 1908, one manufacturer announced that he had abandoned cone-pulley drive. Two years before, this same company offered machines in which the feeds could be selected at will, independently of the cutter speed, on the basis of inches per minute in twelve steps up to 16 in. per min. Lubrication became more important with geared models, and this machine had all parts flood-lubricated with oil delivered by a pump supplied from a tank in the base. All machines were being built heavier and cuts were only limited by the cutters, which had been greatly improved with the introduction of high-speed steel a few years previous. Alloy-steel gears came into use and power rapid traverse became a regular feature. Semi-steel castings also appeared about this time in place of cast iron. Somewhat later ball and roller bearings were placed on the backshafts and more recently on all gear-carrying shafts. Last year the first standard roller-bearing equipped spindle could be obtained.

The most recent advance in milling machine design took place a few weeks ago when nine builders adopted a standardized spindle end, selected not as a compromise, but on its engineering merits. In order to obviate sticking, it has a taper of 3½ in. per ft. and it contains other common-sense features that appeal to the user who has struggled on without them these many years. Forty-four years ago, John J. Grant, writing in the *American Machinist,* advocated straight-shank spindle ends to overcome the same trouble, but lack of provision for compensating for wear prevented the adoption of his design. How diametrically opposite is the solution reached today!

For fifty years the *American Machinist* has been a forum for discussion on milling cutters. Coarse- versus fine-tooth cutters was a favorite subject for disagreement. In 1882 a contributor theorized on the subject and offered experimental evidence in favor of coarse teeth. "The fastest gear cutting I ever saw done was accomplished with cutters having only five teeth," he stated. John J. Grant also advocated coarse teeth a year later and recommended cutting the teeth spiral (36 deg. for general use) to eliminate chatter. However, another contributor stated that "fine tooth cutters are far preferable as regards capacity." But in '88 Charles Beach found he could do more and better work by halving the number of teeth in an inserted-tooth face mill, and applied the same idea to a small end mill with the object of obtaining more chip room.

In 1893, "much better results are obtained from cutters (inserted tooth) with relatively coarse pitch, say about ¾ in. c.p.," one author stated and added that the new cutters failed in old machines, but showed 50 per cent increase in production when placed in heavier machines and supplied with plenty of coolant. Ten years later, coarse tooth cutters were again advocated, this time by Fred H. Holz of the Cincinnati Milling Machine Co. who later published results of tests to indicate that one-third the power could be saved by halving the number of teeth. He also favored faster speeds. It was not until after the publication of De Leeuw's tests in 1911, however, that coarse-tooth milling cutters were definitely accepted and marketed as standard. One of these, a nicked, spiral cutter, 4½ in. in diameter with 10 teeth, had four times as much chip space as used heretofore. Tests indicated that with the improved cutters 1 cu.in. of metal could be removed per hp.-min. as against 0.6 cu.in. with the old style cutters. The tooth pitch of inserted-blade cutters was also increased.

The first mention made of inserted-tooth cutters was in 1883, when John J. Grant described a face cutter 12 in. in diameter, having a cast-iron body and six round, inserted teeth of Mushet steel. A cutter of unusual size was reported in 1889. It was 91 in. in diameter, had 42 inserted teeth and took a 3-in. cut in armor plate. With a cutting speed of 23.5 ft. per min. it removed 75.6 cu.in. of metal per minute. In 1894, cutters were first shown with teeth inserted in radial slots milled in machine-steel bodies.

Inserted-blade spiral mills were made in Germany as early as 1884, but none were introduced in this country until 1892 when George Bechtol made the first one. It was 15 in. long and 5 in. in diameter and had a cast-iron body. The spiral-wound blades were held in corresponding grooves with a type-metal binder. In 1905, C. O. Peck improved the method of mounting and shaping the blades, by that time made of high-speed steel, and later published the results of tests showing that 43 cu.in. per min. could be removed from a steel forging with one of these cutters.

IN 1883, Grant maintained that the work should be fed against the cutter rotation, but a decade later an animated discussion took place as to the relative merits of cutting with or against the feed or, as the conception then was with equipment none too rigid, springing the arbor as against lifting the work. The argument became so heated that considerable editing was necessary before the letters appeared in print. Nowadays, we mill against the feed quite as a matter of course.

Fifty years ago, 20 ft. per min. was a normal cutting speed in cast iron with a feed of a few inches a minute. By the early nineties, speeds had jumped to 50 or 60 ft. per min. and feeds as high as 5 in. per min. One record cut was made with 11½-in. feed, and a feed of 18 in. obtained in gear cutting was considered "simply unbelievable," but even in 1903 machines were supplied with feeds only up to 6 in. per min. However, even then heavy cuts were being taken in medium-carbon steel at the rate of 4 in. per min., which was considered, and *was,* very high. A year later one company was successfully milling cast iron at a cutter speed of 82 ft. and a feed of 27 in. per min. with spiral mills and later increased these to 100 ft. and 30 in., respectively.

Feeds in steel also followed apace. Where in '98 1 in. per min. was high, in 1909 feeds as high as 9½ in., equal to present practice, were attained.

Presses and Their Application to Metal Industries

SO FAR as authentic history records, the first power presses of the crank type were built toward the close of the eighteenth century. Since there had been no considerable mechanical power available before that time to drive them, the incentive to make them could not exist. If we accept the evidence of old prints illustrating mechanical contrivances of the medieval period, the presses before that time were mostly of the screw or the lever type; a condition logical to conceive, as these are the types to which manual energy is most easily applied.

We are here chiefly concerned, however, with what has been done during the last fifty years in the development of the press as applied to the metal working industries. We know that in the year 1877—the beginning of the period of which we write—crank, screw, lever and hydraulic presses had been reduced practically to their present forms, and that advances since that time have been by way of increase in size, power and rigidity, and in extending the range of application.

An interesting commentary upon the increase in size and weight of presses may be found in the remark made to the writer by a man who in 1870 entered the employ of one of the prominent press-building firms as an apprentice and who is still on its payroll, having seen within his own experience practically the whole range of development. He said: "When the boss foundryman got a shop order to cast a press frame that weighed 3,000 lb. it used to upset foundry routine for a week; now a press does not begin to be 'big' until it weighs a hundred tons."

IN 1877 the making of watches and clocks, a large and important business—no less large and important still, but dwarfed by other and newer lines of manufacture—absorbed no inconsiderable number of the presses that were then built. Interchangeability of manufacture, credit for the establishment of which is usually given to the gun-makers, is vital to the machine production of these articles, and many types of the extremely accurate sub-presses, dies, tools, etc., now universally employed in mass production, were developed by or for the watch and clock factories of New England.

It would be out of the question to enumerate in the space here allotted the multifarious products of the press. As extremes of the included range we might mention some of the almost microscopical parts of a watch at one end of the scale, with bath-tubs, automobile bodies, or the corrugated ends of steel freight cars at the other. From the soft metals of light gage for which the presses of 50 years ago were principally designed the progress has been consistent and rapid until presses of 1,000-ton capacity are common and the drawing of steel ⅜ in. thick is every-day practice.

The manufacture of metal buttons and eyelets developed a type of press with multiple cranks and slides, or a single width slide with four or six cranks and their connections, to carry on continuously and automatically as many progressive operations at once. Many products come, finished, from such a press, having entered as a strip of sheet metal from which pieces are cut, blanked, drawn, folded, swaged, etc., and finally ejected as completed articles. Operations of this kind are often called "cut-and-carry," or if the specific product is an eyelet or similar part, the press may be called an eyelet-machine.

AUTOMATIC feeds came into use very soon after the press found its place in the manufacturing line. Where blanks were to be cut continuously from a strip or coil of metal it was most logical to provide a pair of rolls, which could be given an intermittent motion derived from the crankshaft through a ratchet and pawl to feed the stock to the tools. Dial and gravity feeds are applicable where partly formed blanks are to be fed to a press for a further operation.

In any operation other than blanking, where the immediate product of the tools must be removed before another piece can be placed, there should be some means of getting the finished piece out of the dies without delay and without hazard to the operator. In many cases the result is accomplished merely by making the press inclinable so that it may be tilted to an angle of fifty or sixty degrees from the perpendicular, under which condition the work will fall from the tools by gravity. With some parts it is necessary to provide a jet of compressed air, or even a mechanical ejector.

The eyelet machine and cut-and-carry operations in general made necessary the finger type of feed, by which partly formed blanks are actually lifted out of one die and deposited in the succeeding one while the slide is passing through the upper half of its cycle. While the principle of all finger feeds is the same, their detail is as various as the kinds of work to which they are applied.

Because of its quickness of action; the innocent appearance of its parts when at rest; the convenience of, if not necessity for, having the fingers of the operator under its slide when transferring the work; and, above all, the serious nature of the injury when accident occurs; the crank press has earned, and no doubt deserves, the name of being an extra-hazardous machine, and many devices have been brought forth to reduce the danger.

These devices are usually based upon one or the other of two principles. In one of them a movable gate is attached by levers to the mechanism of the clutch so that if any obstruction, such as the operator's hands or wrists, prevents the gate from closing, the press cannot be tripped. The other principle involves the use of two hand-operated trip-levers, neither of which alone will trip the press. Both must be depressed at the same time, and if the operator's hands are upon the widely-separated levers they cannot be under the slide.

As drawing and forming operations were applied to larger and still larger articles the size of presses increased accordingly, and where a multiple-crank press of fifty years ago might be as much as 36 in. between housings and weigh 3,500 to 4,000 lb., we may now find them with a corresponding dimension of 20 ft. and a total weight of 300 tons. Presses with crankshafts of such length require a positive drive at both ends of the shaft in order to prevent wringing the latter and thus throwing all of the burden upon the crank nearest the driving gear.

With the application of greater powers the unaided belt is no longer able to drive the machine; thus very early in the cycle of evolution we find back-geared presses with two and even three geared speed reductions to allow it to make up in velocity what it lacks in direct pulling power. Large gears for presses were first made with cast teeth, and were noisy, inefficient in the matter of power transmission, and subject to breakage at most inopportune moments; hence we find most of the modern press gearing to have cut teeth.

The advent of the electric motor affected the design of presses but little, though many of the larger ones are now driven by independent motors. The flexibility provided in the drive by the interposition of the belt between motor and fly-wheel makes for easier starting and is often employed; though many presses are entirely gear driven. Motors of fractional horsepower are often applied to small presses, in which case the belt drive is retained to ease the shock upon the motor when the blow is struck.

Presses, usually of the multiple-crank, progressive operation type are often employed to make forgings for small manufactured articles, and they do it with a speed and precision impossible to hammer work. On especially heavy forging operations the hydraulic press is used; the enormous power available and the flexibility of control render this machine especially adaptable to the work. Hydraulic presses are also applied to many operations outside the metal working field.

AN OPERATION that is analogous to forging is that of extruding. In this work a billet is heated to plasticity, placed in a closed chamber and forced through the shaped die that forms the end of the latter. Pinion rod and a variety of special shapes are produced in this way from non-ferrous metals.

Soft metals, such as tin, lead, etc., are extruded cold, generally with hydraulic presses but in some cases with crank presses. An example of this is the production of thin-walled metal tubes in which oils, artists' colors, tooth pastes and materials of similar consistency are distributed. For this purpose a press with a swinging punch holder is employed. The tube, when extruded, surrounds the punch, and it is for the purpose of stripping it therefrom that the punch swings out of line with the die at the top of the stroke.

The toggle-joint press is a type that has a wide field of application for the reason that the toggle is capable of augmenting enormously the pressures delivered by the unassisted crank. Small and medium-sized presses of this kind are used for coining metals, and hence are called coining presses. They are also used for drawing, and drawing presses of the toggle-joint type are among the heaviest and most powerful presses in the world.

DROP-HAMMERS are not presses, but they are in a way allied with them, and the press manufacturer is in most cases a builder of drop-hammers as well. As distinguished from the press the work of a drop-hammer is done by a blow instead of by pressure. Machines of this type are extensively used for forging, and also in many cases to give the final shape to an article that has been brought to this stage by press-drawing. Such an operation is called stamping.

Though much less complex than their big brothers, the presses, they have gone through much the same process of evolution. Fifty years ago, a drop-hammer that weighed 100 lb. was unusually large, and all of them were operated by manual effort. Now we may find them with heads weighing as much as 3,000 lb., and, of course, demanding a corresponding amount of power to run them.

Of whatever type a press may be it is primarily a device for the application of pressure; it does not become a production machine until it is fitted with tools to perform a specific operation. In view of the fact that its cost is a minor consideration compared to the expense of making and maintaining the tools used in connection with it, no small proportion of the engineering thought and study of press builders and users is directed toward the design of tools to secure the maximum production per unit of cost.

Making press tools has become an important branch of the industry and all large users of presses maintain special departments for that work. Special machines have been developed for making dies, including automatically controlled milling machines with which they can be reproduced from wood, metal or plaster models or templates of the part. These machines require little attention from the operator after the preliminary setting, and with them dies are made for a fraction of the cost of the hand methods ordinarily employed.

The greatest destructive agency in the operation of press tools is the slight misalignment possible where one member is secured in the slide and the other clamped to the press bed; a trouble greatly augmented by careless setting. To minimize this trouble the sub-press was devised. This is a mechanism to contain a complete set of tools the parts of which are permanently and accurately located with respect to each other, and is ready for service without further adjustment by merely securing it in any type of press that will impart to it the necessary relative motion. Its rigidity of construction and the accuracy with which it maintains alignment of tools enable it to prolong the life of the latter materially.

If the present tendency persists the price is destined to assume a commanding position in the metal industry. Pressed steel is replacing castings with ever-increasing rapidity.

Evolution and Application of Production Grinding

FIFTY years ago the process of machine grinding was applied principally to the work of sharpening tools and to correcting errors caused by distortion in hardening machined parts of tool steel that had already been completed by other means. Aside from natural sandstones, which were used in even greater numbers in the relatively smaller field of industry than they are now in the larger one, grinding wheels were made principally of emery grains, cemented together by sodium silicate, rubber, or shellac; or glued to the leather covering of wooden disks.

As a commercial proposition the grinding wheel was of minor importance. A few firms made them by the silicate process, and wheels bonded with rubber or shellac were fairly common. A wheel of 12-in. diameter by 1 in. in thickness was considered large, and by far the greater number of wheels that were used, especially of the wooden disk wheels, were made in the shops that used them. Vitrified wheels were unknown.

Whereas the activities of the early grinding machines were confined to the removal of minute quantities of stock from work-pieces that could be machined in no other way, the process of production grinding contemplated the substitution, in a measure, of the abrasive wheel for the steel cutting tool to reduce rough forgings to finish size and symmetry within limits both of time and dimension that had not hitherto been attained.

Even though some super-inventor had conceived and built a modern production grinding machine fifty years ago it would have availed him nothing, for at that time there would have been no wheels to test its capacity; the materials from which real grinding wheels are now made had not yet been discovered.

DURING the last decade of the nineteenth century two men working independently and with different materials toward the same end (which end, by-the-way, was far removed from the making of production grinding wheels) brought to light almost by accident the two substances that have made production grinding possible. These substances are silicon carbide and aluminous oxide; each masquerading under a dozen or more trade names, but probably best known as carborundum and alundum, respectively.

Some years before the new abrasives were ready the process of making grinding wheels by bonding them with vitreous clays—as a potter makes his ware—had been put into practice, so that nothing further stood in the way of production grinding but lack of experience, or, rather, absence of vision to conceive its possibilities.

The first production grinding machines, though so far in advance of contemporary practice as to bring upon their designers the ridicule of grinding machine men, were light in weight and deficient in power when compared with modern machinery of their type; yet they were able to force the then available grinding wheels beyond endurance. Improvements in wheel making were followed by more powerful machines, and those in turn by still more effective wheels. Thus, since 1900, the wheels and the machines have developed together; each supplemented by, yet dependent upon, the other.

SEPARATE types of machines were early developed: machines to grind round work externally; to grind holes in work pieces small enough to be rotated; to grind cylinders truly round and parallel internally; to grind plane surfaces; and many special machines adapted to grind one kind of piece, but to produce that piece in unlimited quantities.

Rates of speed of table and traverse movements, once calculated in inches per minute, have been increased as experience and experiment dictated until a speed of 50 ft. per minute is not uncommon and of 100 not impossible. Where wheels were once considered a source of danger at a peripheral speed of 3,000 ft. per minute, modern wheels of similar size and kind run at double that rate with perfect safety.

Where once was to be found a machine that two men armed with pinchbars could move around and set up without difficulty, we now find some of them weighing 50,000 lb. and more. From a diameter of 12 or 18 in., wheels have increased to 36 and even 60 in. Wheels that once were wide at 1 in. may now be found with 16-in. width of face.

The 1-in. single belt that fifty years ago seemed amply capable of driving any grinding wheel to capacity has been replaced in some instances by 6-in. belts of double thickness. And if this were not sufficient emphasis upon the vast increase in the amount of power absorbed by grinding machines, some of them have their wheel heads mounted directly upon the rotor shaft of a 75-hp. motor, and require at times all of the energy the motor is capable of delivering.

Where speeds are high and pressures heavy the wheel has become a steel chuck in which blocks of abrasive material are securely fastened. Breakage in service of such a wheel means nothing, as the broken pieces cannot get out of the chuck.

One of the major problems to present itself early in the development of grinding machines having reversing tables was to provide reliable mechanisms to move the heavy weights. While this has been taken care of by suitable gearing in many cases, we must not overlook the hydraulic system of table drive in which a cylinder

and piston are substituted for the gears, and reversal is accomplished by means of a valve in the pressure line instead of a clutch. Rotary hydraulic motors, driving the table through pinion and rack, have also been used where the length of stroke would necessitate an inordinately long cylinder.

"Plunge-cut," "set-wheel," or "form" grinding reduces a piece to size and contour in one movement of the wheel radially, without traverse, toward the axis of the rotating work. Both parallel and tapered, as well as shouldered work, are done in this manner by first shaping the face of the wheel. "Multiple-wheel" grinding is a modification of this process in which two or more separate wheels are used on one spindle, their relative diameters and contours suited to those of the work.

THE centerless grinding machine, a development of the last ten years, grinds round pieces parallel, tapered or even shouldered, without need to center them. The work piece is supported upon a suitable rest between two wheels running at different speeds, being rotated by the slow moving wheel and ground by the fast one. The magnetic chuck, designed in 1896 first as a magnetic brake for trolley cars and later adapted to hold work on the surface grinder of the toolroom, has become an integral part of many types of production machine and has contribufed in no small measure toward high rates of production by lessening or entirely eliminating the set-up time.

Automatic, or hopper, feeds have been applied to grinding machines on small work with success. Automatic sizing devices on all types of grinding machines have transferred to the machine the operator's burden of anxiety, and where he was wont to approach his final sizes with great caution and with frequent application of gage or micrometer, he now adjusts the mechanism to deliver a certain size and leaves the machine practically to itself; sure in the knowledge that it will produce indefinitely to within half-thousandth limits.

The readiness with which the grinding wheel generates heat and the difficulty of grinding round and straight because of it was an unfortunate condition against which the sponsors of production grinding had continually to contend. The early machines were provided with pumps and piping to deliver a dribble of water about the size of a lead pencil on the wheel and work, and more often than not even this small corrective influence was overlooked or deliberately avoided. In contrast with this some modern machines are equipped with a system of coolant circulation that will handle 100 gallons of liquid per minute.

To consider the less imposing but hardly less important phases of the evolution of grinding let us look at the swing-frame grinder of the foundry and cleaning shop. Here a wheel 12 in. or more in diameter with 2-in. face is mounted on a universally suspended and balanced frame wherewith it can be manipulated almost as readily as the hammer and chisel, file and scraper, that were superseded by it. Such wheels may be driven by motors of 5, 7½ or even 10 hp., and the amount of work a man is able with their aid to accomplish is increased almost by the ratio between his own manual energy and the power that drives the wheel. The combination of the small electric motor with the grinding wheel, as in the case of "toolpost" grinders, "hand" grinders, etc., has placed in the hands of the mechanic a tool that enables him to accomplish much of the work hitherto performed with a file and scraper, or with a stick with a piece of abrasive cloth tacked to it, and to do it with far less effort in a much shorter time.

Disk and belt grinding machines, developed from the sanding machines of the cabinet-maker and pattern-maker, have kept pace with the march of progress. Originally employing sheets of sandpaper or emery cloth glued to cast-iron disks, these machines have increased in size and power as well as in range of applicability as their first grinding mediums have given way to improved forms of abrasive disks and heavier abrasive belts until they are indispensible in their particular fields.

With all the advance in power, in rapidity of production and in range of application made possible by the artificial abrasive wheels and machines to swing them, accuracy has been enhanced, not sacrificed. We not only produce in thousands where we formerly produced in dozens or hundreds, but we are enabled at the same time to secure uniformity of product measurable in split-thousandths instead of binary fractions.

The process of lapping, formerly used only by the toolmaker to correct slight inaccuracies, has been extensively applied to manufacturing operations, and machines have been developed for the purpose that accomplish, almost automatically and upon thousands of parts, what the toolmaker effected at the expense of much time and labor upon his single piece of work.

Lapping is strictly a finishing operation and is seldom expected to remove more than one or two ten-thousandths of an inch of material. Small though it is, however, it is stock that would otherwise be worn away in the first few hours a machine is in operation, and by removing it before assembly the life of the machine is materially prolonged and quietness of running is secured. In other words it is the "running in" operation transposed; a machine with its parts lapped before assembly is ready for service without preliminary trial. Finely powdered alundun, carborundum, garnet, glass, and to some extent diamond dust, are used as abrasive mediums in lapping operations.

HONING, a development of the past few years, is a finishing operation—applied principally to finishing cylinders of automotive engines and work of a similar character—that employs artificial abrasives in a somewhat different manner. The cylindrical hone is made up of segments consisting of blocks of the abrasive material, and is provided with means of expansion. It is revolved at a comparatively slow rate of speed in the cylinder to be finished, and at the same time is given a reciprocating movement to forestall a tendency to grind rings in the work. It is seldom allowed to remove more than 0.0015 in. from the diameter of the bore.

It is not to be understood that modern production grinding machines and processes have supplanted other machines and methods; rather have they supplemented them, and created for themselves new fields of application. They do, largely, what no other type of machine can do. By reducing costs of manufacture and extending the field of manufacturing possibilities they have exercised upon the machine industry an influence hardly second to that of the steam engine of James Watt or the slide rest of Henry Maudslay.

Welding, a Development of This Generation

FORGE welding is as old as metal working and nobody knows exactly how old that is. Yet it was the only form of welding practiced when the *American Machinist* was founded. It is typical of the marvelous strides taken in mechanical development during the last fifty years that all of our present methods of welding and cutting by gas or electricity have come into being during that period, and largely within the latter half of it.

In its early days welding, either by gas or electricity, was looked upon principally as a repair job. The "putting-on tool," facetiously longed for by our fathers, was at last an actuality. It is still an invaluable salvage medium but it has also come to be an important manufacturing tool.

The clean, readily controllable heat of the electric current early suggested the form of welding known as resistance welding, and more specifically as butt welding, seam welding, spot welding or tube welding, depending on the application. In butt welding the parts are shaped, pressed together and heated to welding temperature by a heavy current of low voltage. Further pressure upsets the joint and completes the weld. Butt welding machines have been made larger and larger as confidence in them grew until there is now available a machine that will weld a joint 40 square inches in cross-section.

By means of seam welding machines all sorts of relatively thin-walled metal containers are put together at high speed and low cost. Where the joint does not have to be water-tight spot welding provides the best method known. A double row of staggered spots properly spaced gives a joint as strong as the plates themselves. Although spot welding is essentially a thin-section process it can be used on ½-in. plates and has been used experimentally on 1-in. plates. Tubes are produced by rolling up sheets and welding the edges together by resistance welding. Speeds of 60 to 150 ft. per min. are in common use. If alternating current is employed at these speeds the weld is not continuous but consists of a series of spots or "stitches" as they are called. Hence the term "stitch-welding."

ANOTHER form of welding by means of electricity that is now widely used employs the heat of the electric arc to melt and deposit metal in a recess, either to repair a defective part or to join two parts together. Electric arc welding is done with a metallic electrode, coated or bare, or with a carbon electrode, in which case a filler rod supplies the additional metal. Quite recently, satisfactory results have been obtained when the welding is done in an atmosphere of atomic hydrogen, the molecules being broken down by the heat of the arc; also when the electrode is surrounded by a jet of hydrogen, water gas or alcohol vapor. Arc welding can be done with either direct or alternating current provided the appropriate apparatus is available.

Gas welding, as it is now generally called, uses the heat developed by the burning in the presence of oxygen, of an inflammable gas, usually acetylene, to melt a metal filler rod into a recess in a piece of metal, or the joint between two pieces. Tanks of oxygen and of acetylene are readily obtainable and there are on the market a number of different types of torches for combining the two gases in the proper proportions.

Of almost equal importance to industry is cutting. Quite remarkable "plumbing" jobs in heavy steel piping have been done with the torch and it has had wide use in the demolition of steel structures. The salvaging of material from the ships condemned under the limitation of naval armament agreement would have been greatly hampered without the torch. Mounted in guiding machinery the torch becomes a production cutting tool that competes with machine tools. For salvaging sunken steel vessels its ability to function under water has proved to be invaluable.

THERMIT welding occupies a field that overlaps those of the other branches of welding to a certain extent but is mostly its own. For repairs on heavy parts that have broken in service, such as rudder frames and sternposts on vessels, locomotive frames, crankshafts and rolling mill rolls, it has saved many thousands of dollars. It is also used to joint street railroad rails.

The process consists of enclosing the parts to be joined in molding material which is shaped around a wax collar that has previously been worked around the parts. The wax is melted out and the cavity filled by the molten steel resulting from the brief reaction in the portable thermit crucible. Steels of various ultimate strengths can be obtained by varying the composition of the crucible charge.

Welding has come to occupy an important place in metal fabrication. To list the fields in which it is not used would be easier by far than to enumerate those in which it has won a place. It is still subject to at least one serious disadvantage—the human element. Much depends on the skill and honesty of the operator. As technique improves and control approaches more nearly to perfection new fields will open to the welder. Two are of prime importance: The fired and unfired pressure vessel, and the steel frame building. Rapid progress has been made in these two fields within the last year and it is reasonable to believe that the remaining problems will be solved within a short time.

Advances in the Coating of Metallic Surfaces

PRIOR to 1877 there were any number of formulas and recipes for bronzing metals. Electro-plating had been invented and was in commercial use. Coating with zinc was done by using zinc sulphate as the electrolytic solution. Cadmium had been deposited as a coating but without any useful application. Galvanizing had been in use for a very long time. Browning and bluing of ferrous metals were common, particularly in the small arms factories. Bronzing and coppering were known. Lacquering, japanning, and painting were the other early principal processes of protecting metallic surfaces against corrosion.

In France, the art of bronzing alloys, called bronzes, developed early. The chief constituent of such alloys was copper; they contained also tin in varying amounts, zinc, and other metals. *"Verde antique"* of different shades was known prior to 1828. "Bronze Lafluer" was introduced in 1828; smoked Florentine bronze in 1833; and other bronzes still later. Painted bronzes were introduced about 1870, the objects being first brass plated and then oxidized with a mixture of oxide of iron and graphite.

Galvanizing was first done by dipping, without the use of machinery. Then gear-driven rolls were introduced. The sheets were annealed in boxes in coal-fired furnaces. Still later rolls were used through which the sheets were passed from the pickling bath of muriatic and sulphuric acid to the galvanizing solution. The operation of corrugating was introduced at a relatively early date.

Coppering of metals was very popular as one of the early finishes. The objects were dipped in a solution of copper salts until this method was superseded by electroplating. Tinning was used to some extent, the methods of contacting, dipping, and boiling being employed.

METAL spraying did not develop until after 1910. About that time Dr. M. V. Schoop of Zurich, conceived the idea, and it has been due largely to the developments of his inventions that the process is a commercial success. By metal spraying any metal available in wire form and fusible in the oxy-hydrogen flame can be deposited on practically any surface. Such depositions are protection against corrosion and oxidation even at relatively high temperatures.

In the metal spraying process the wire is melted in an oxy-hydrogen flame in a wire-melting pistol and is blown upon the surface by means of compressed air as the wire is fed automatically. The coating thus deposited consists of minute metal particles closely interlocked. Such coatings can be filed, turned, milled, drilled, and otherwise machined if they are thick enough and have been applied properly. Sandblasting, and preheating the article to be sprayed, are aids to adherence.

In all finishing processes it is essential that a clean surface be the basis, whether obtained by polishing, buffing, brushing, a chemical action such as pickling, or some other process. Sandblasting has proved to be a very valuable method. The principle of cleaning by sand in a blast of air was embodied in a machine by Benjamin Chew Tilghmann in 1871. No doubt the device was crude compared to present equipment.

A very compact analysis of "finishing" is given by Field and Bonney in their book, "Chemical Coloring of Metals." In substance, they say that corrosive metals, to be protected from corrosion, should (a) be coated with non-corrosive metals, such as zinc or tin, or with paints and varnishes, or (b) with a layer of "the *product of rusting* when it is a stable product, thus preventing further change."

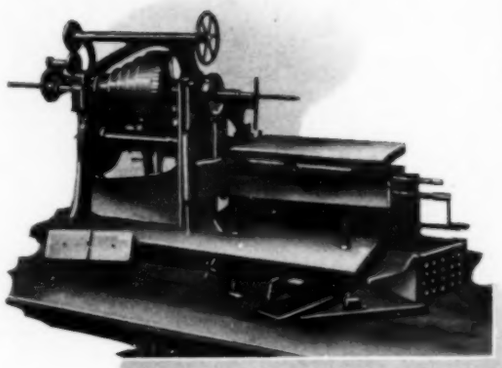
THE fifty-year period since 1877 has seen remarkable developments in adapting machinery to metal finishing. Galvanizing has become largely an automatically controlled process. Electroplating is another finish that has been developed to employ extensive equipment. Formerly the simplest of tanks, hangers and electric devices were involved, whereas now there is a multiplicity of tanks, conveyors, automatic continuous filters, and other equipment.

The features of the modern plating department are: Continuous production, the elimination of back-and-forth movements by the operators, disposal of steam and fumes, automatic filtering of solutions, the elimination of much of the trucking, and complete control over the composition of the solutions and the electric density of the plating baths.

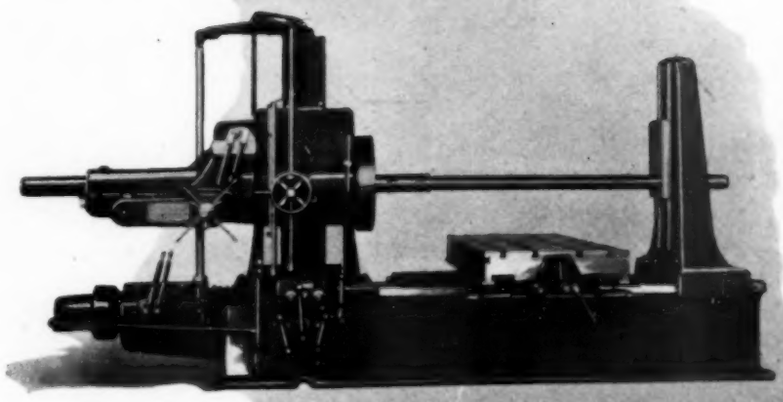
Lacquers, always popular, are today applied on a gigantic scale, the greatest single user being the automotive industry. Lacquers are solutions of materials in volatile solvents. Upon application, the solvents evaporate, leaving a protective film of the solute. Pyroxylin lacquers, favored for automobile bodies, contain pyroxylin dissolved in amyl acetate.

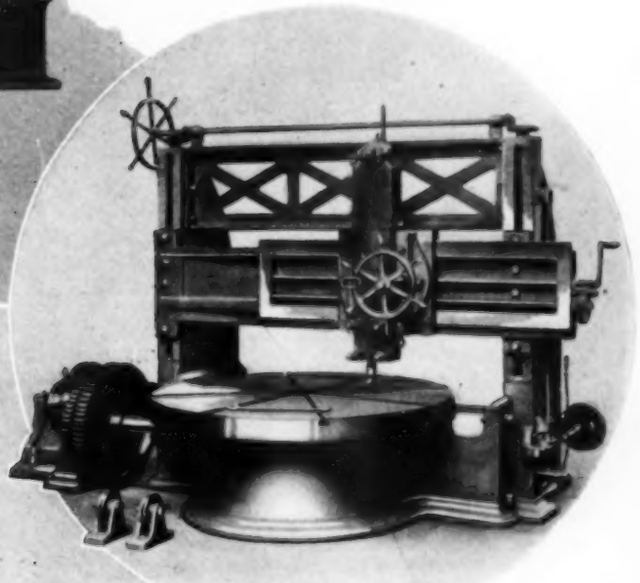
Comparatively recent developments in methods of finishing include: Parkerizing, by which the surface of the ferrous metal being coated is changed, chemically, to form basic iron phosphates, insoluble in water and permanent in the air; Sherardizing, by which zinc, in the form of dust, is applied while both it and the object being coated are heated below the melting point of zinc; and chromium plating, an electro-plating process, which is now the subject of much interest and considerable experimenting; and cadmium plating.

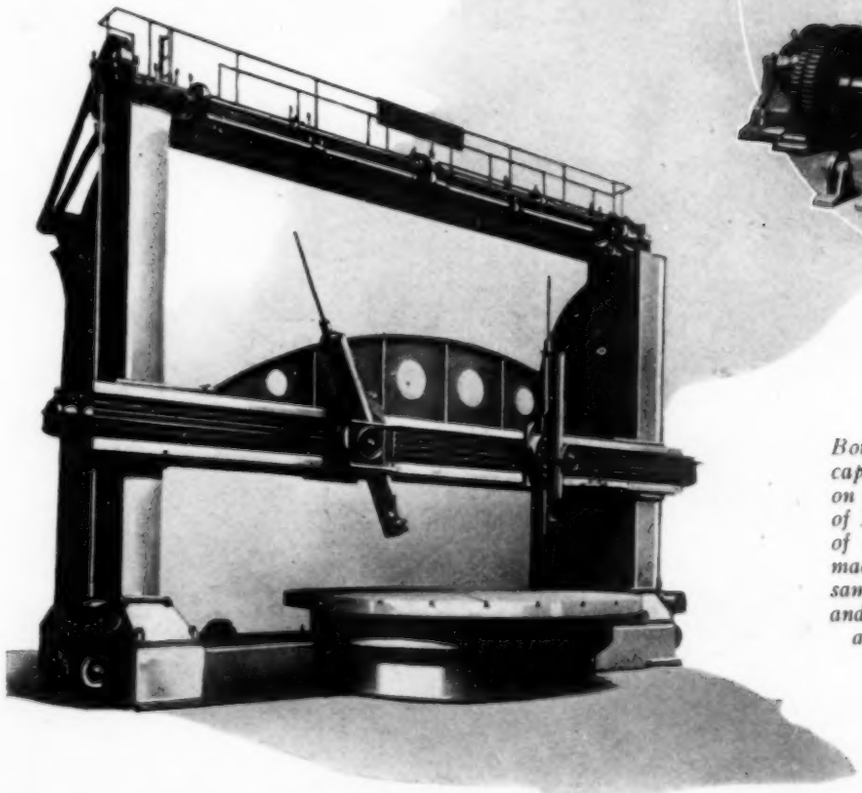
Fifty Years of Machine Tools



ONE reason why machine tools continue to be the Master Tools of Industry is to be found in the ceaseless efforts of their designers and builders to make them better fitted to the needs of their users. The illustrations that follow have been gathered to show something of what has been accomplished in fifty years



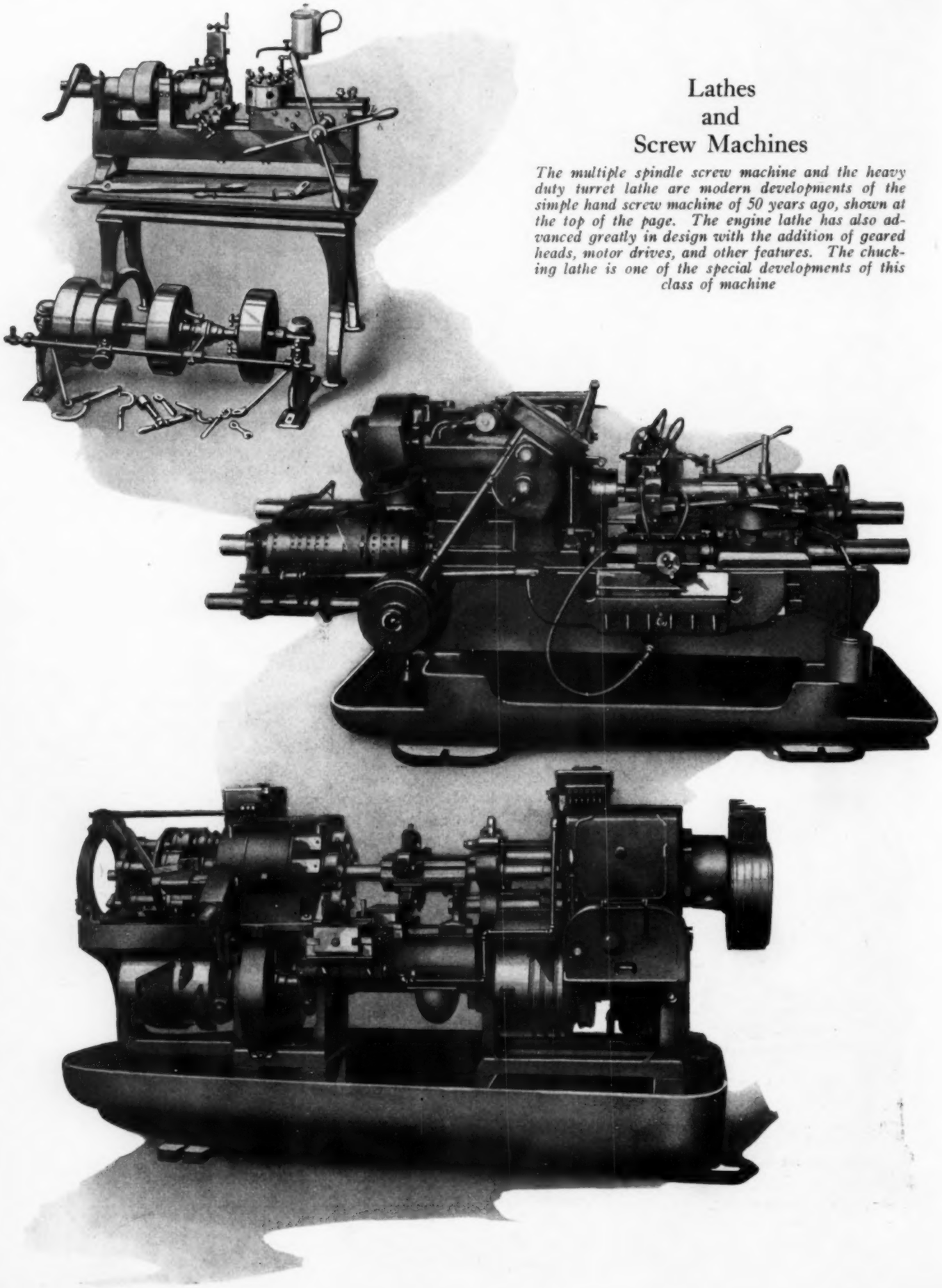




Vertical and Horizontal Boring Mills

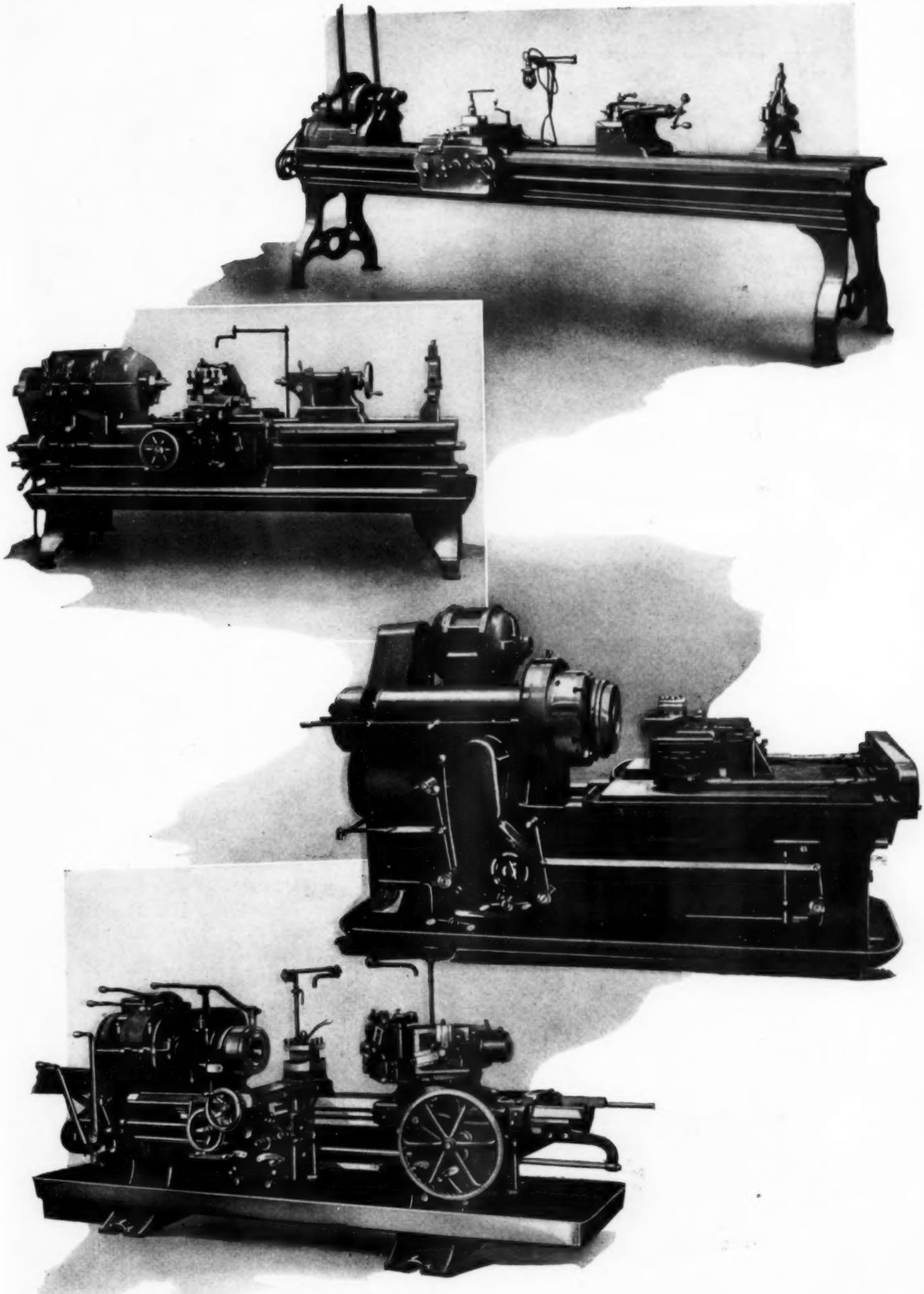
Boring mills have increased both in weight and capacity in the last half century. The pictures on this page are of an 8-ft. vertical boring mill of 1875; a 35-ft. machine of the same type but of the present time; an old horizontal boring machine; and an up-to-date machine of the same type. The first machine has a single head and the bearing part of the rail does not extend all the way from one housing to the other

Fifty years of machine tools

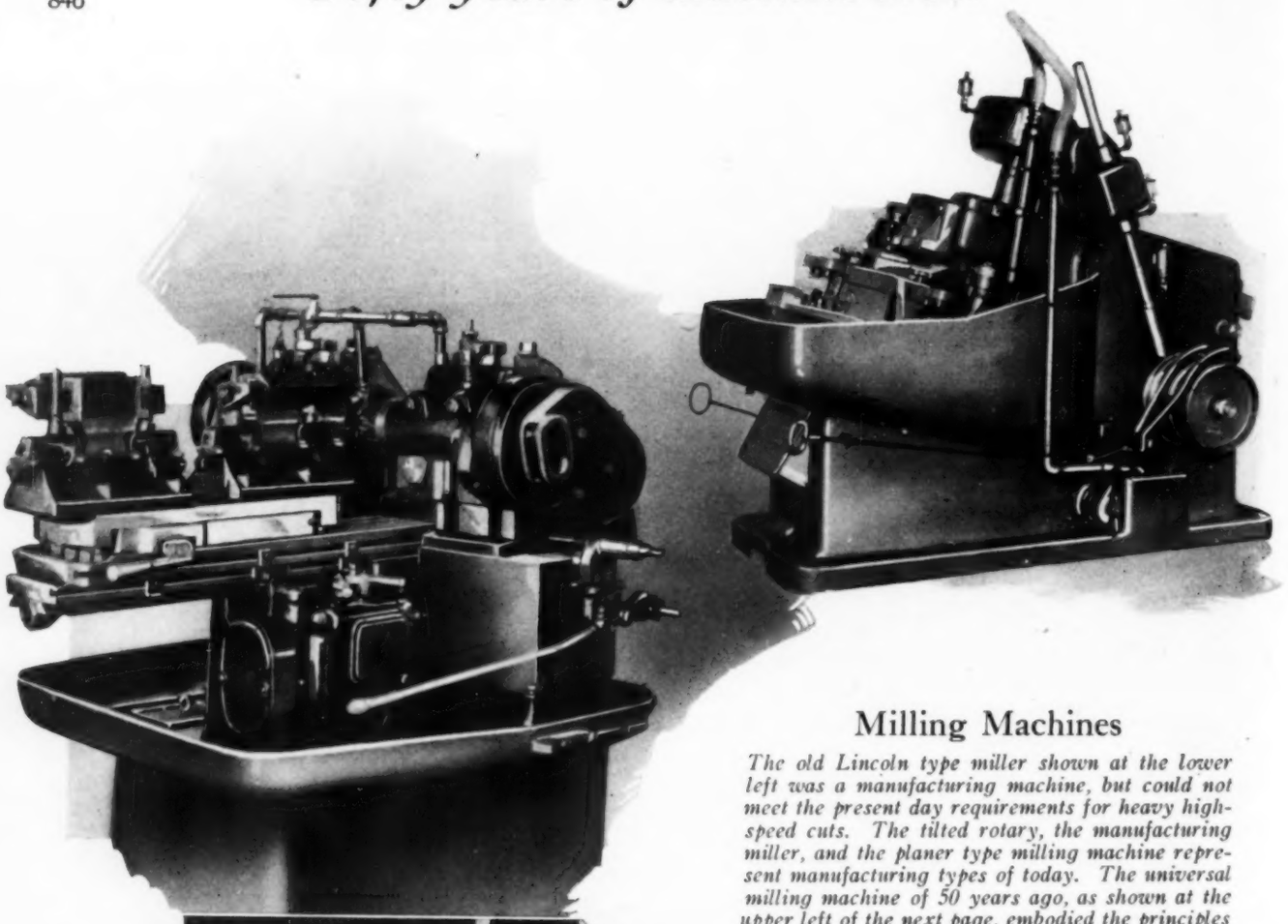


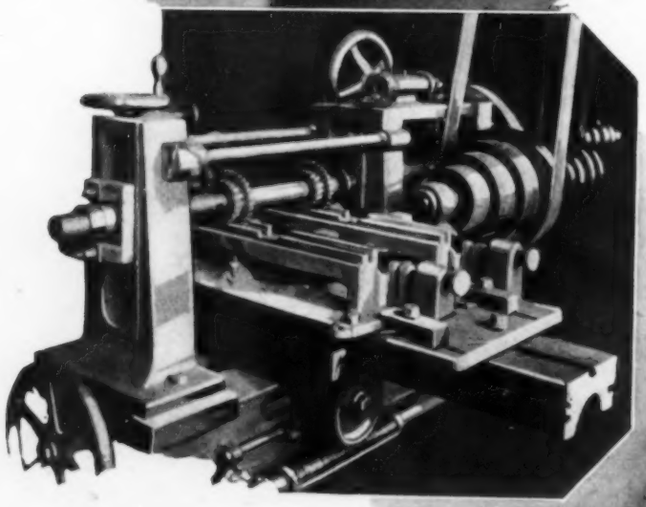
Lathes and Screw Machines

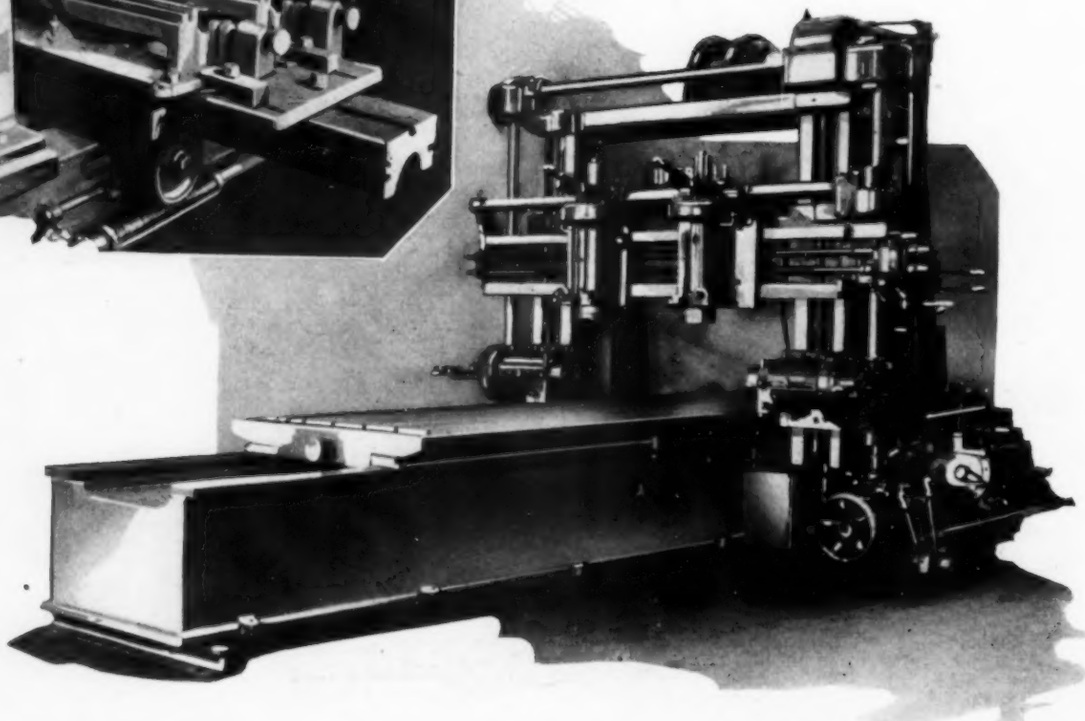
The multiple spindle screw machine and the heavy duty turret lathe are modern developments of the simple hand screw machine of 50 years ago, shown at the top of the page. The engine lathe has also advanced greatly in design with the addition of geared heads, motor drives, and other features. The chucking lathe is one of the special developments of this class of machine



Fifty years of machine tools

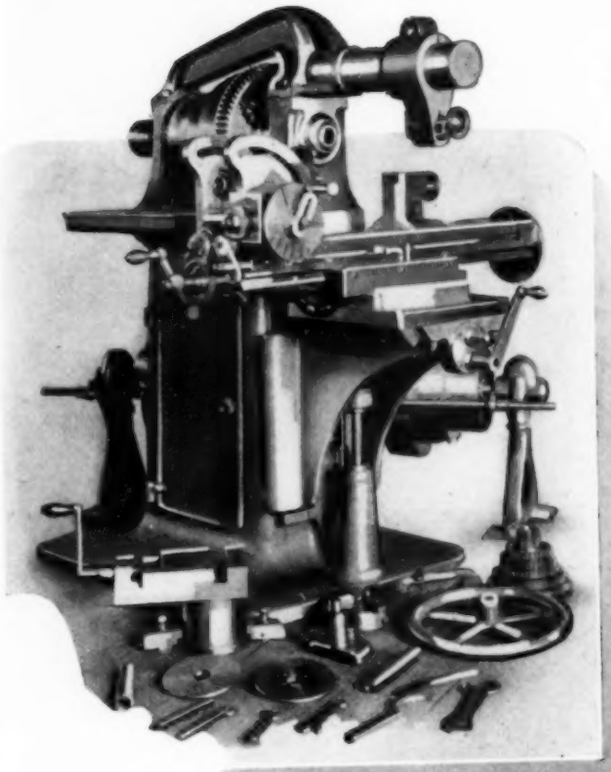


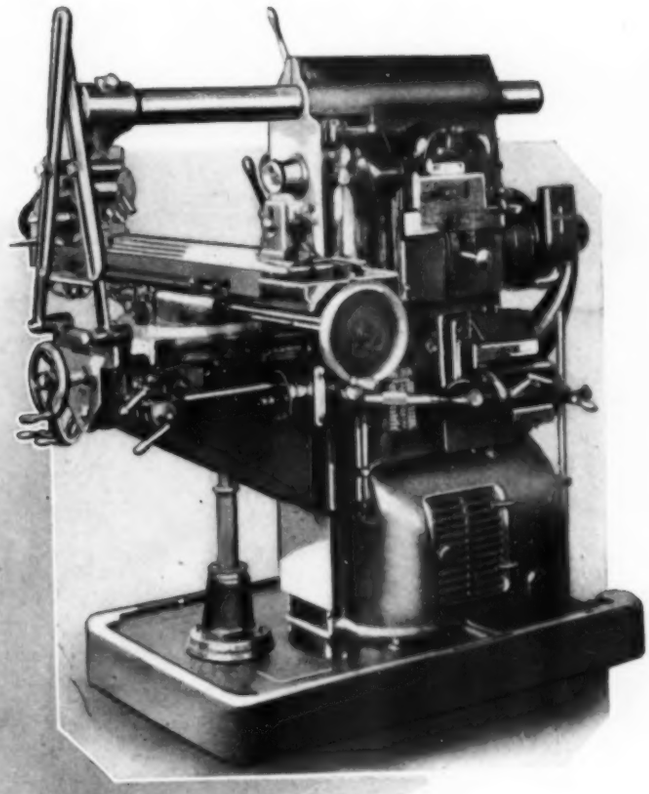


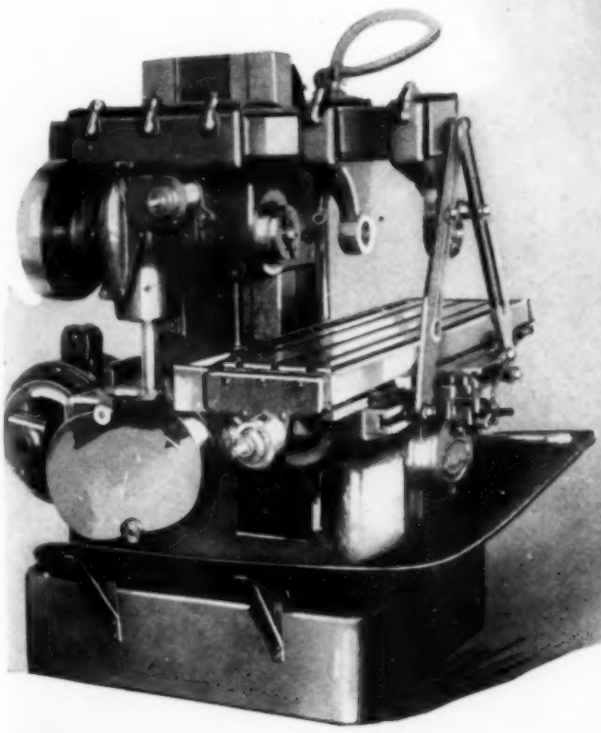


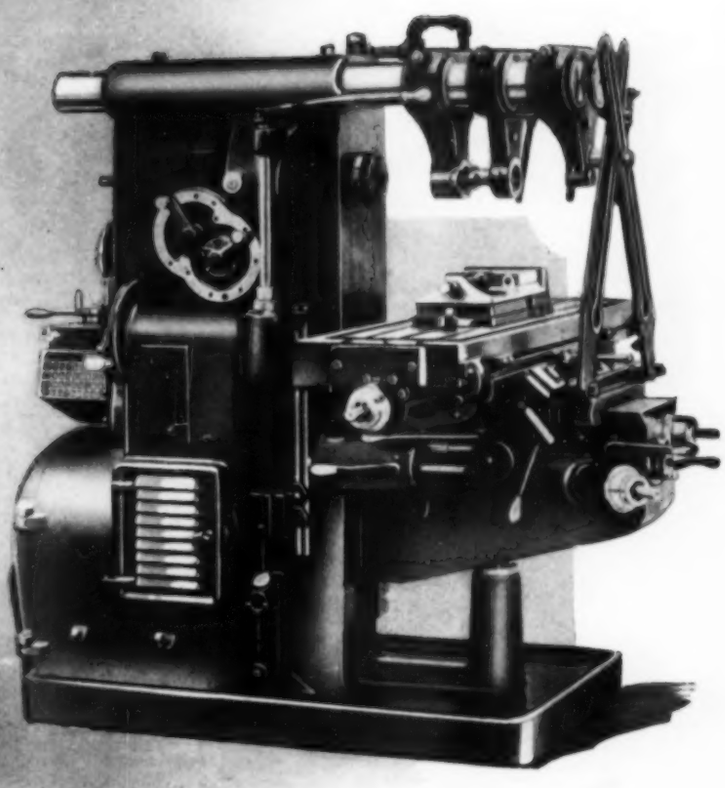
Milling Machines

The old Lincoln type miller shown at the lower left was a manufacturing machine, but could not meet the present day requirements for heavy high-speed cuts. The tilted rotary, the manufacturing miller, and the planer type milling machine represent manufacturing types of today. The universal milling machine of 50 years ago, as shown at the upper left of the next page, embodied the principles of the present design, but the modern machines, as illustrated, not only give the accuracy required for toolroom service, but also incorporate the strength and automatic traverses needed for production work. Motor drives are included in the machines of today

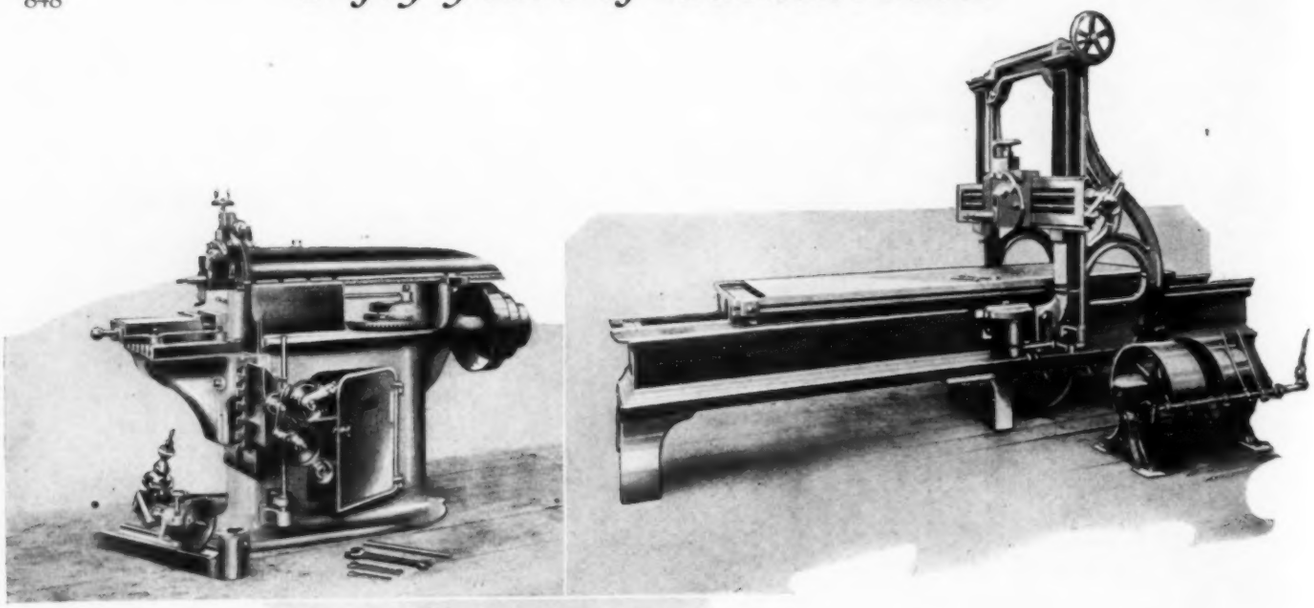






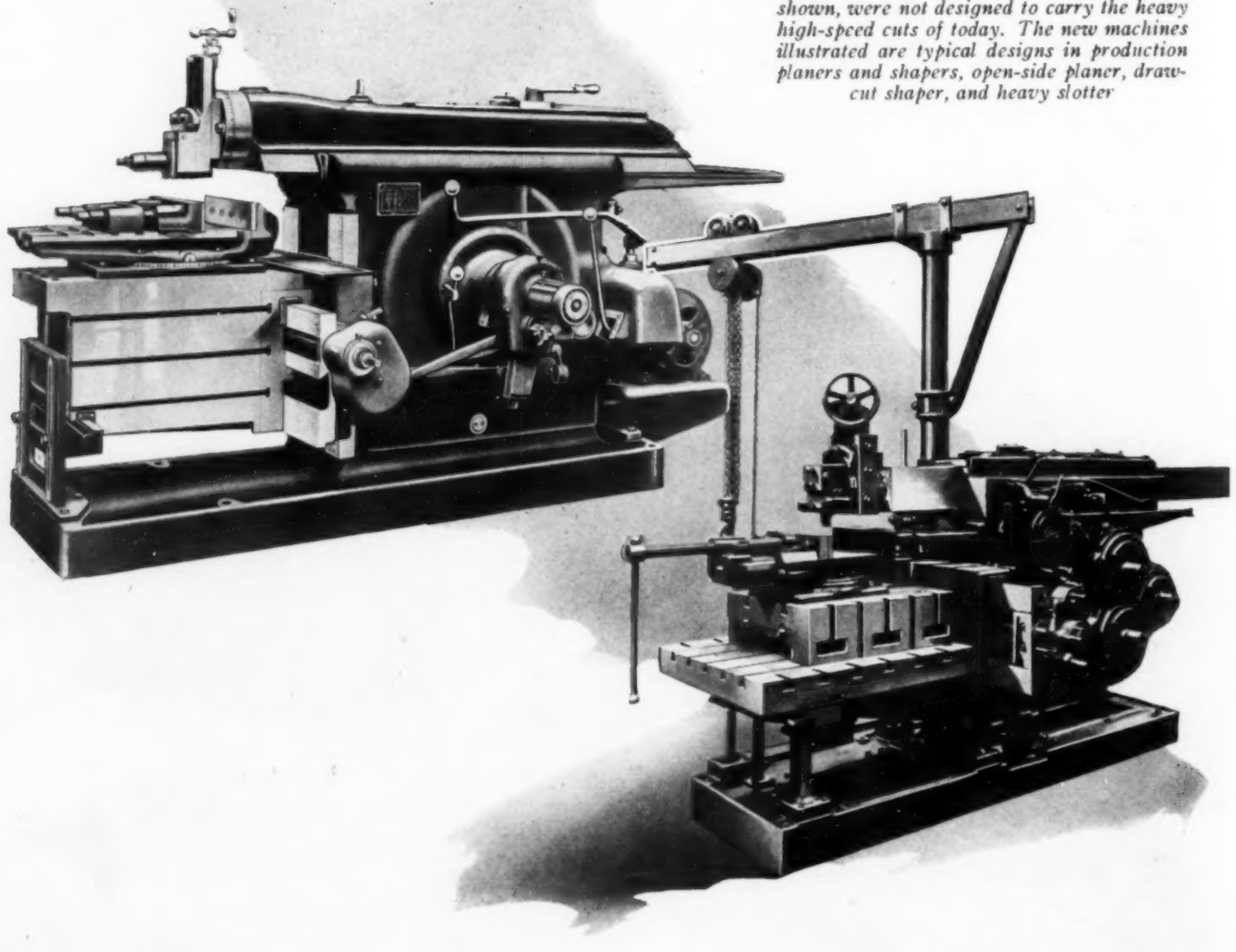


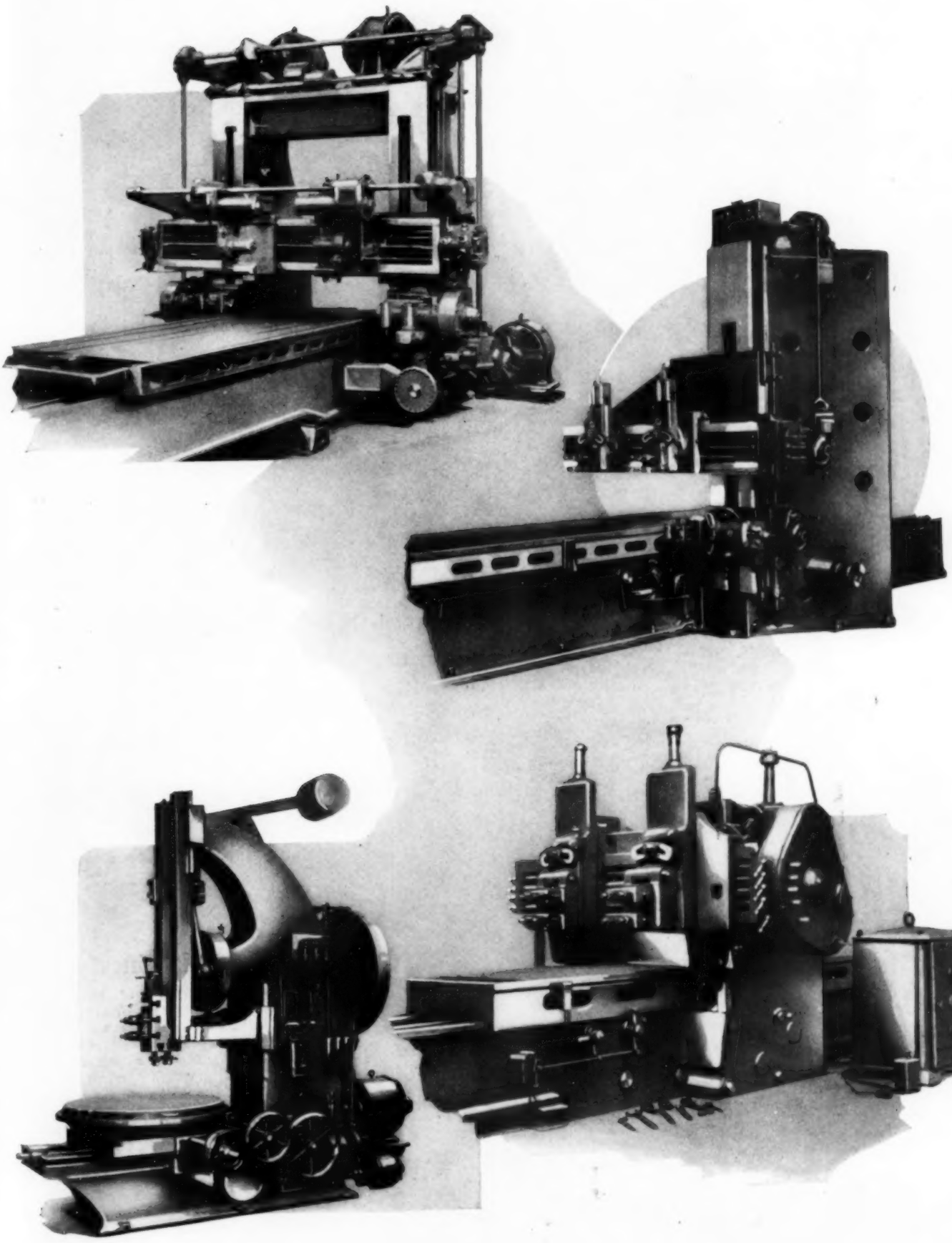
Fifty years of machine tools



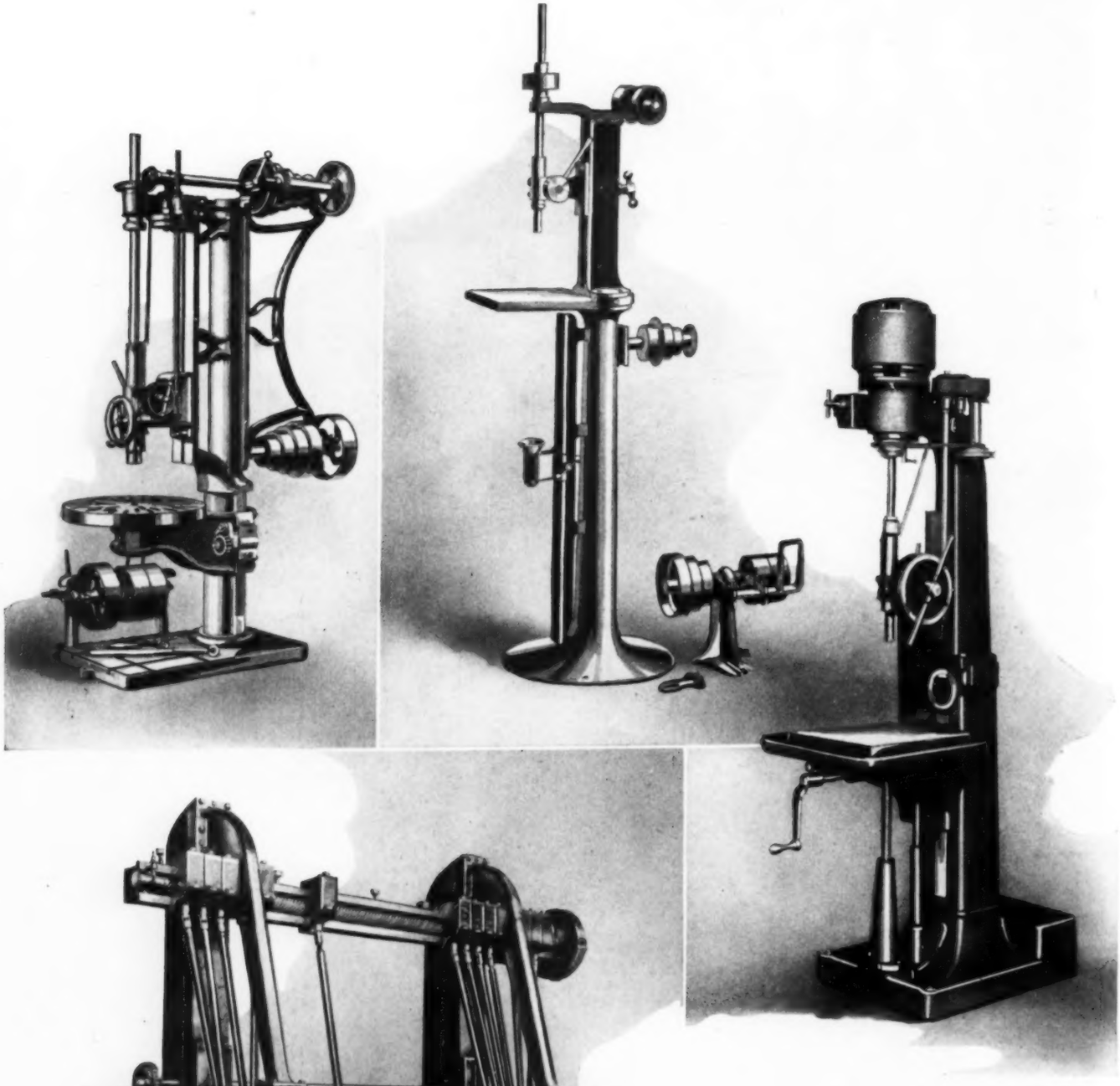
Planers, Shapers and Slotters

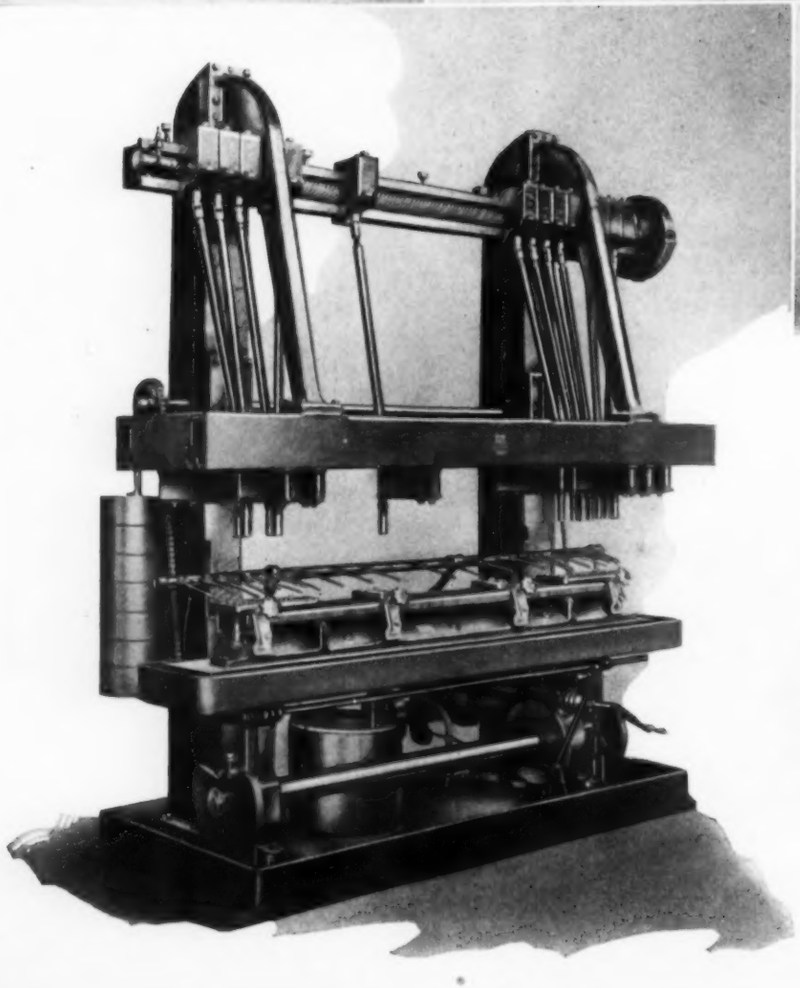
Planing and shaping were early developed as machine shop operations, but the old shaper and the planer of 50 years ago, as shown, were not designed to carry the heavy high-speed cuts of today. The new machines illustrated are typical designs in production planers and shapers, open-side planer, draw-cut shaper, and heavy slotter





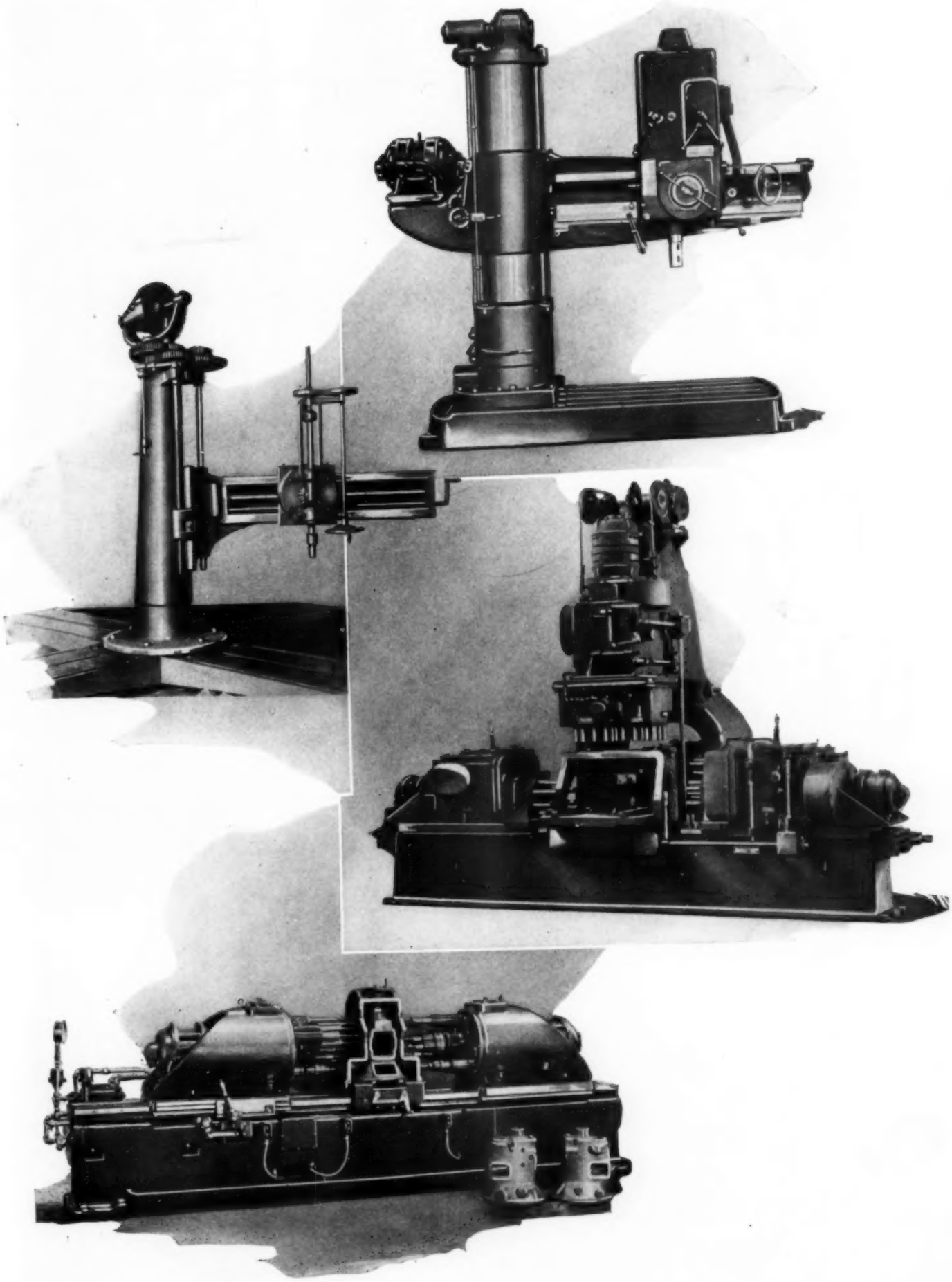
Fifty years of machine tools



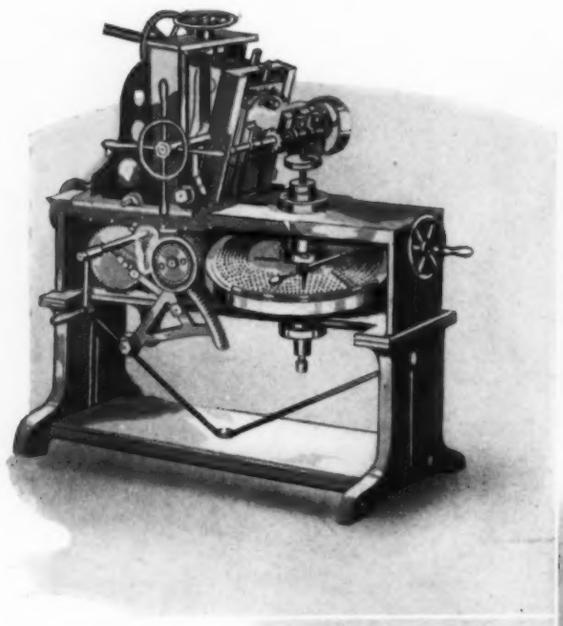


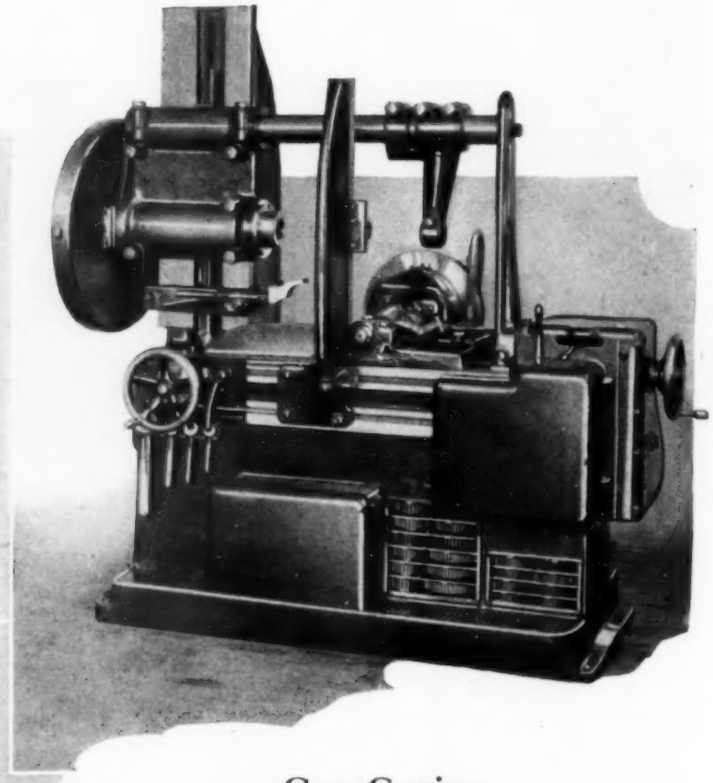
Drilling Machines

High speeds and heavy cuts have called for complete redesign of all parts of drilling machines in the last 50 years. Convenience of operation and motor drives have also affected design. At the top are shown an upright drill and a sensitive drill of about 1877, and a modern sensitive drill. At the left is a multiple spindle driller with universal joint head. At the top of the right hand page is shown a radial drill of today as compared with one of 50 years ago. Below are illustrated a modern horizontal duplex drilling machine and a multiple spindle way driller



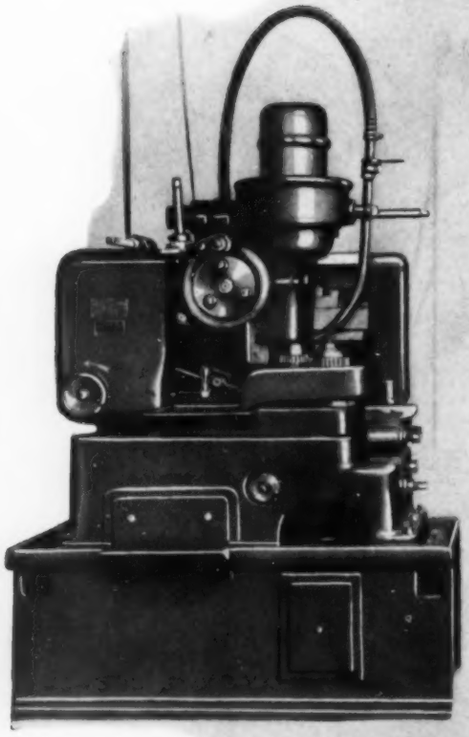
Fifty years of machine tools

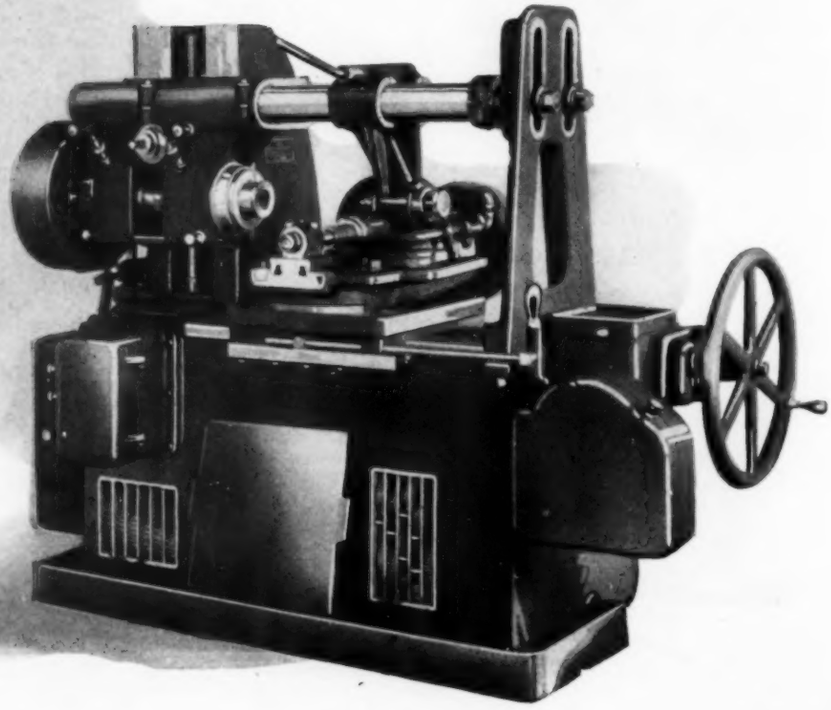


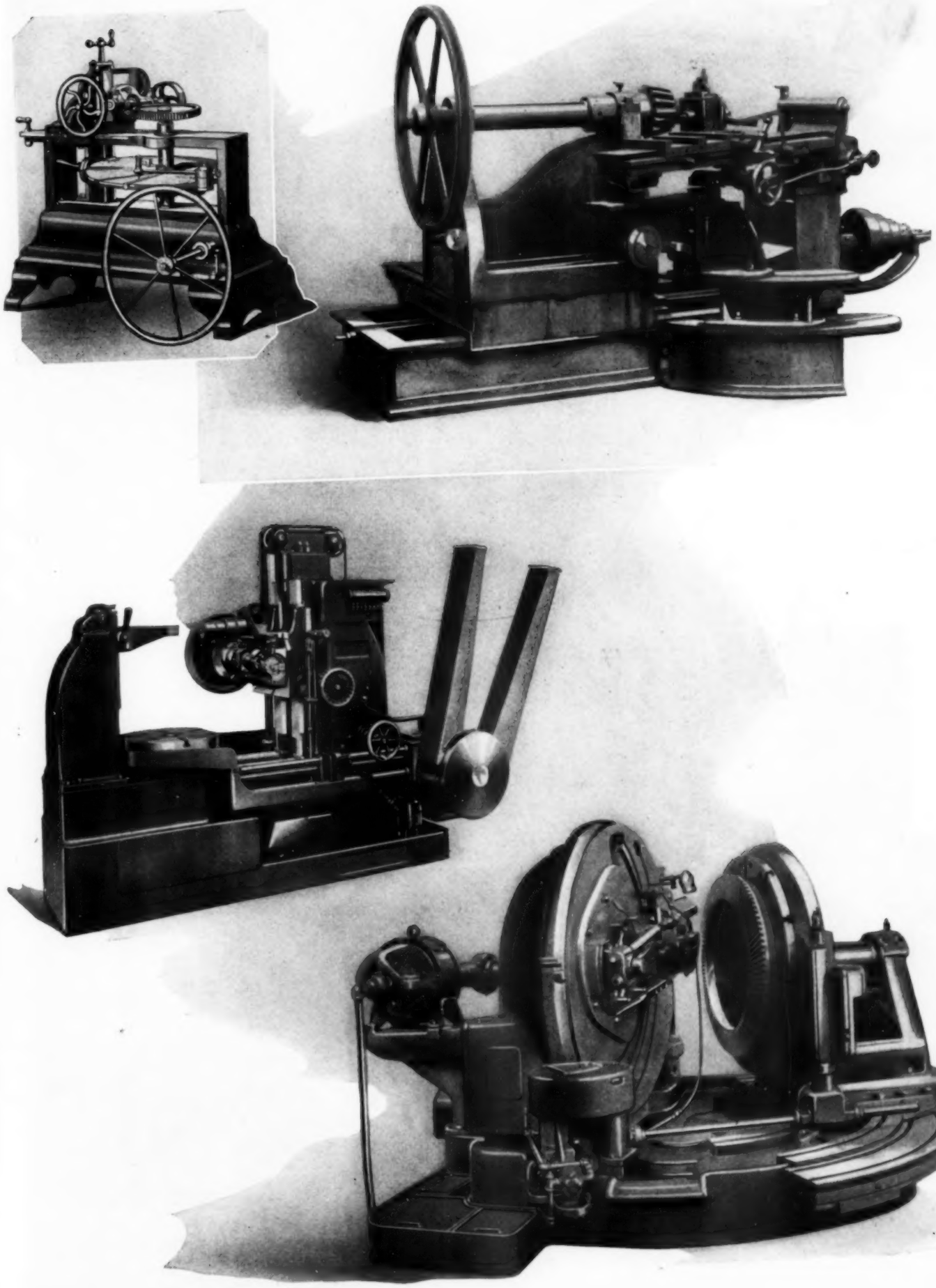


Gear-Cutting and Gear-Generating Machines

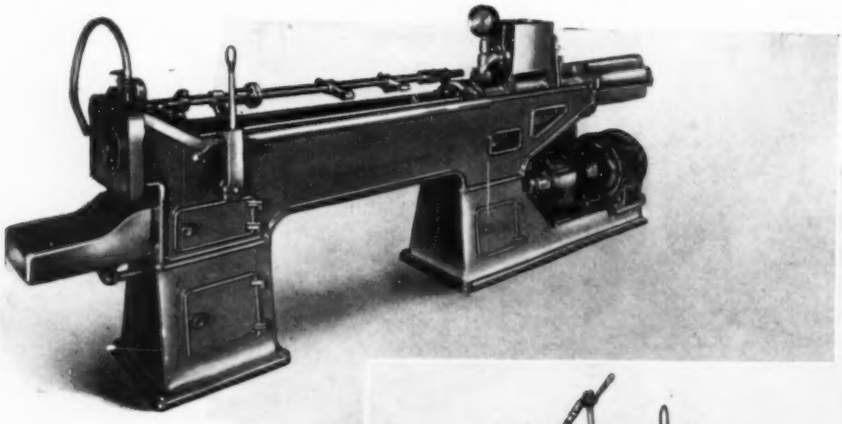
The gear-cutting machines of half a century ago were simple in design and operation as may be seen from the first picture on each page. The gear cutting machines of today are nearly all automatic, and embrace such types as hobbing machines, machines using single rotary cutters, gear planers, gear shapers and gear hobbers. Probably the automotive industry has been the greatest factor in stimulating the design of machines for producing accurate gears that will run with but little noise

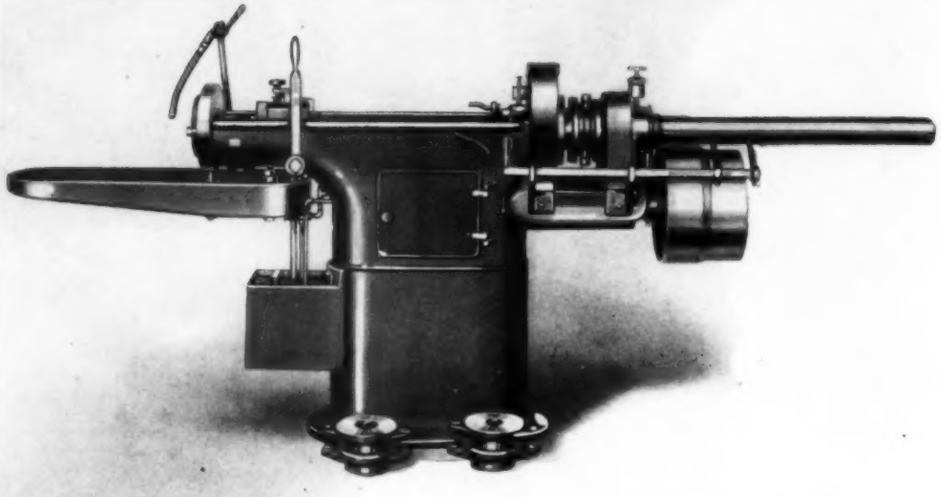


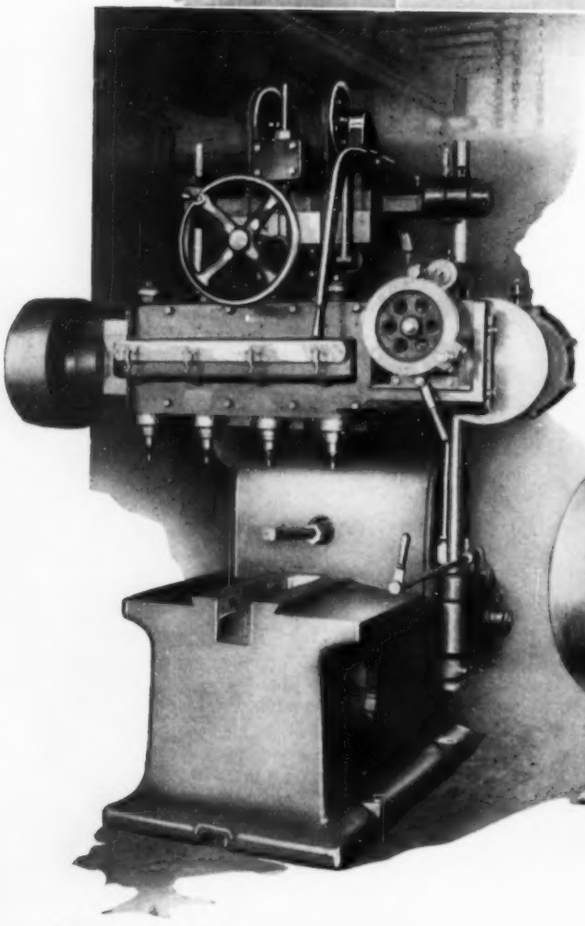




Fifty years of machine tools

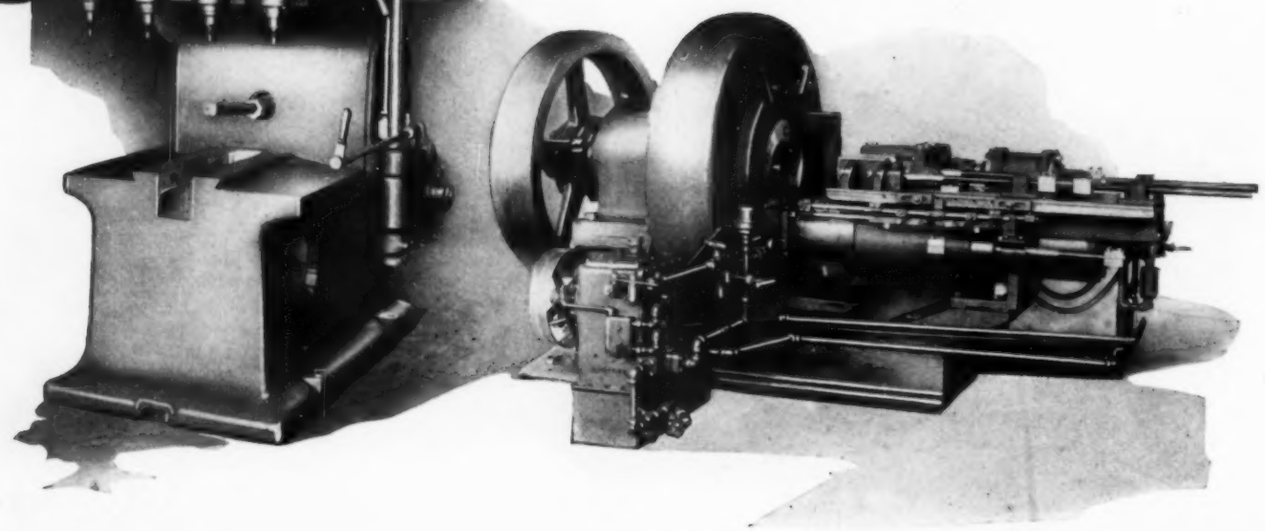


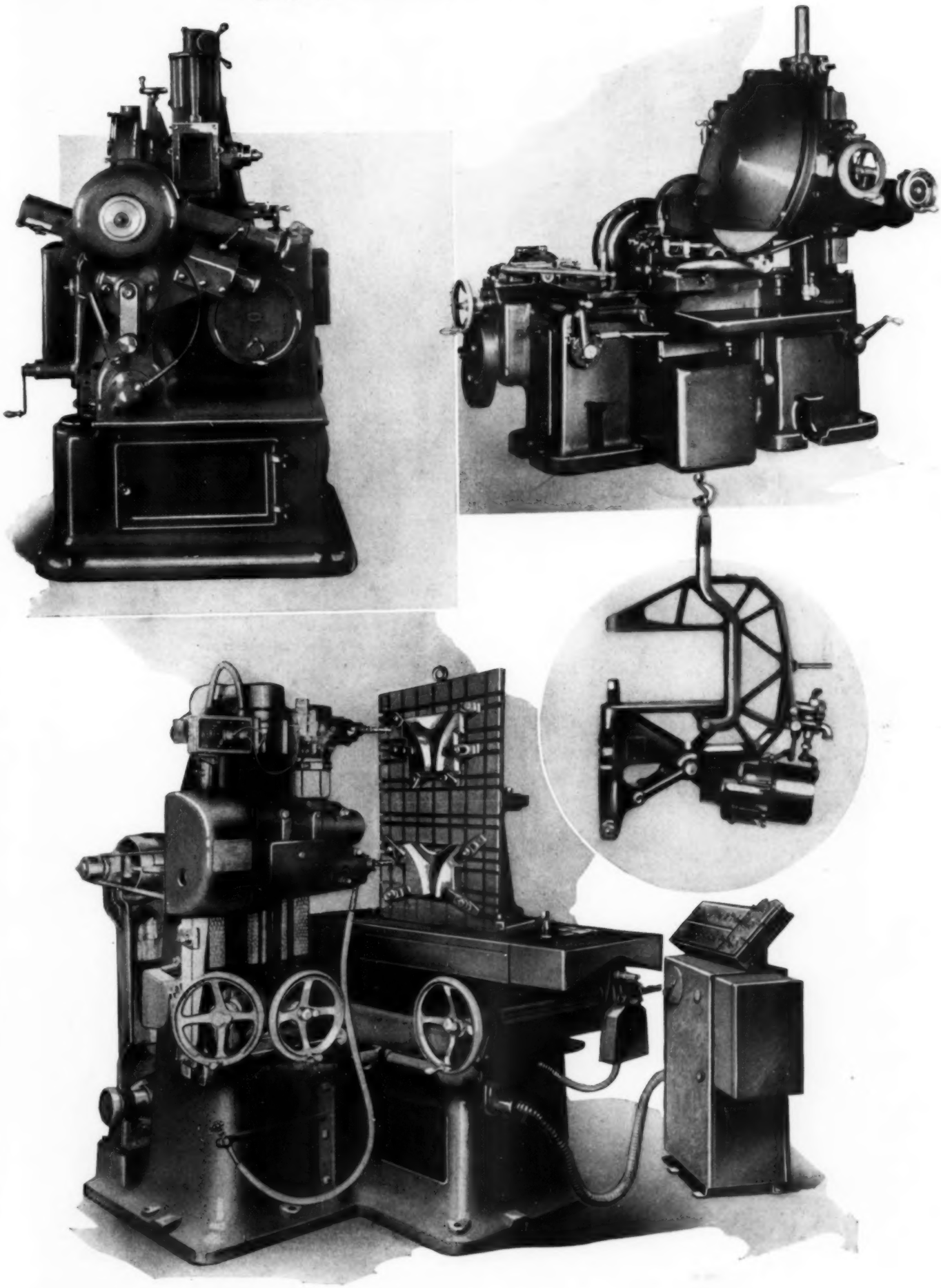




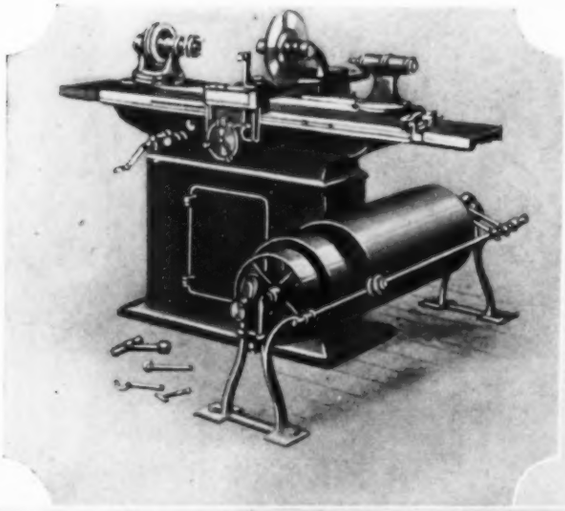
Special Process Machines

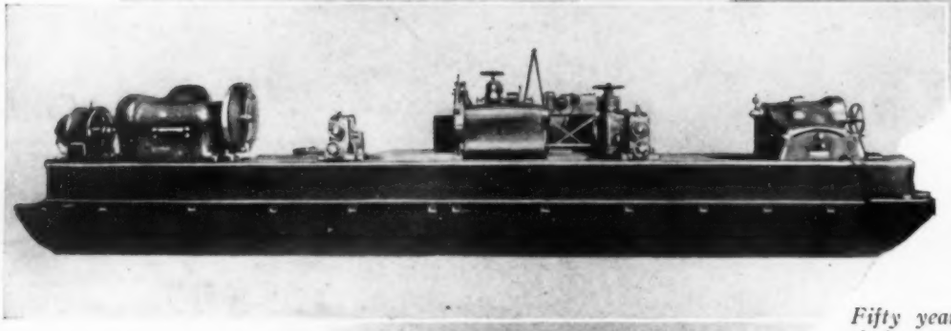
The hydraulic broaching machine and the short stroke rapid production broach for sizing irregular shaped holes represent types of modern special process machines for the production shop. The swaging machine and the multiple spindle automatic profiler also fall into this class. On the next page are shown two automatic gear grinders, a portable riveter for heavy structural work, and an automatic die sinking machine





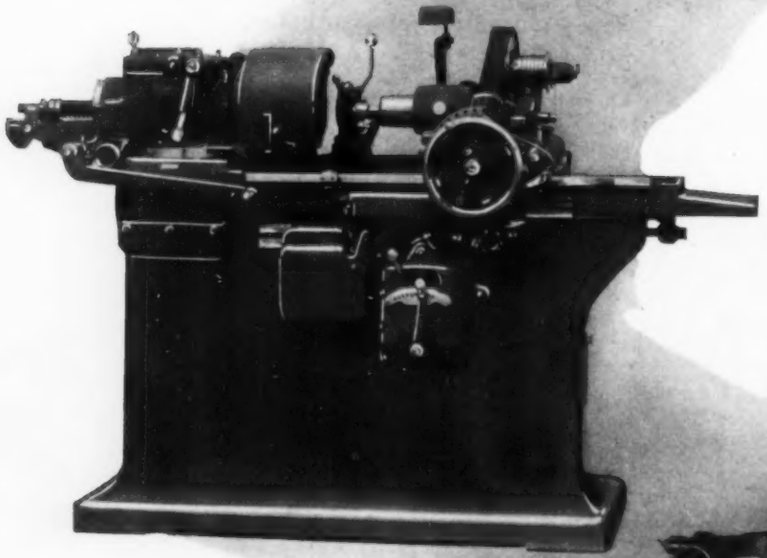
Fifty years of machine tools

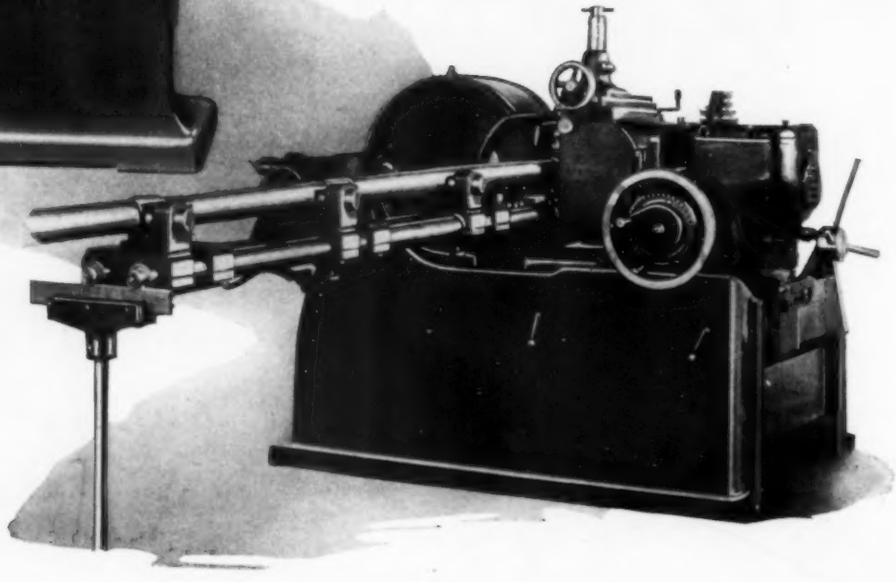


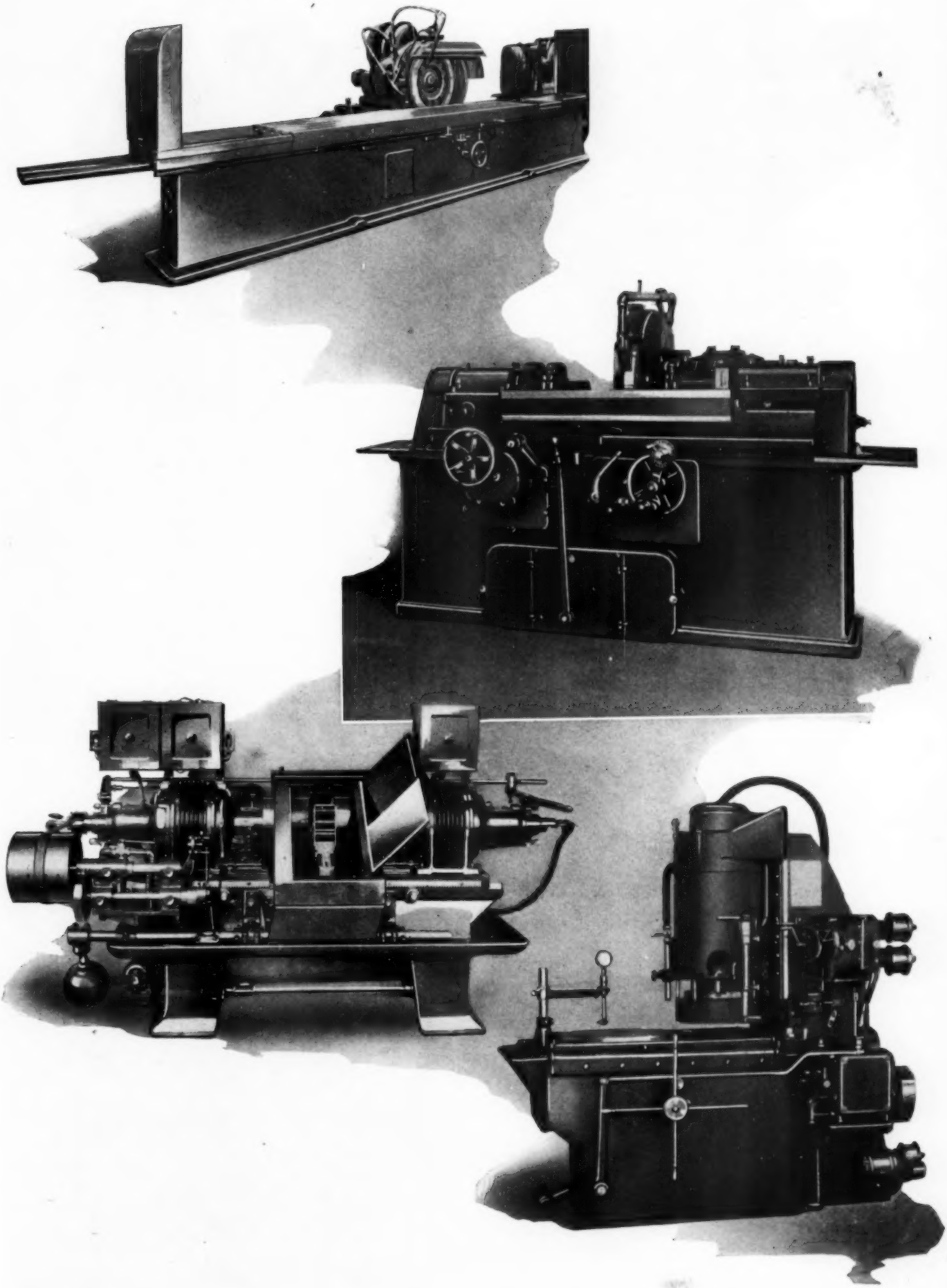


Grinding Machines

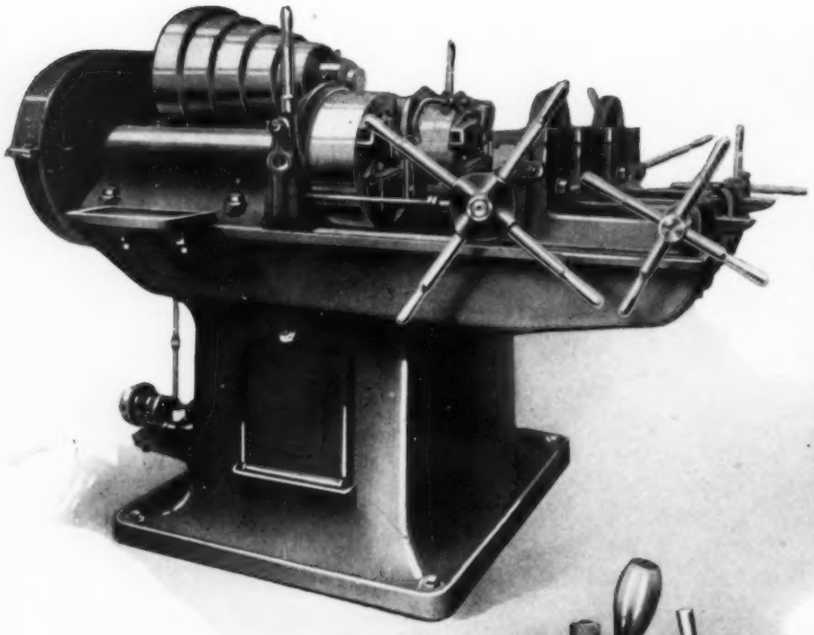
Fifty years ago grinding was almost entirely a toolroom operation, and the original universal grinder and cutter grinder shown represent the highest state of these machines at that time. Toolroom grinders are now built for extreme accuracy, while grinding has been extended to include accurate production work of many kinds. Modern production grinders are illustrated in the views shown of the roll grinder, internal grinder, centerless grinder, face grinder, crankshaft grinder, disk grinder and surface grinder. A typical special purpose machine is the crankshaft grinder shown

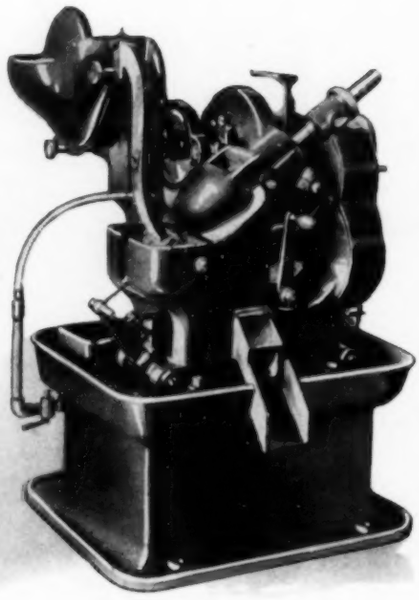


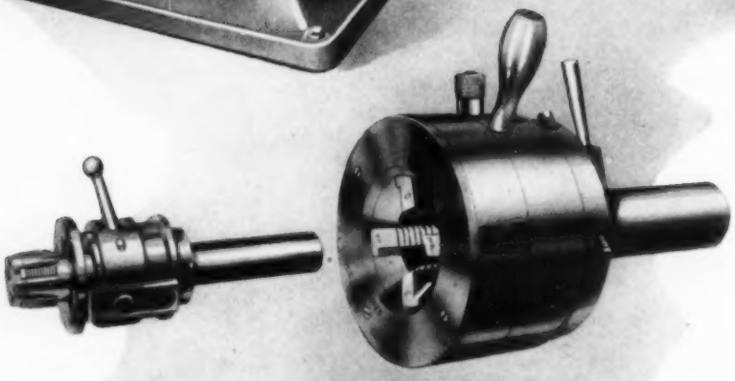




Fifty years of machine tools

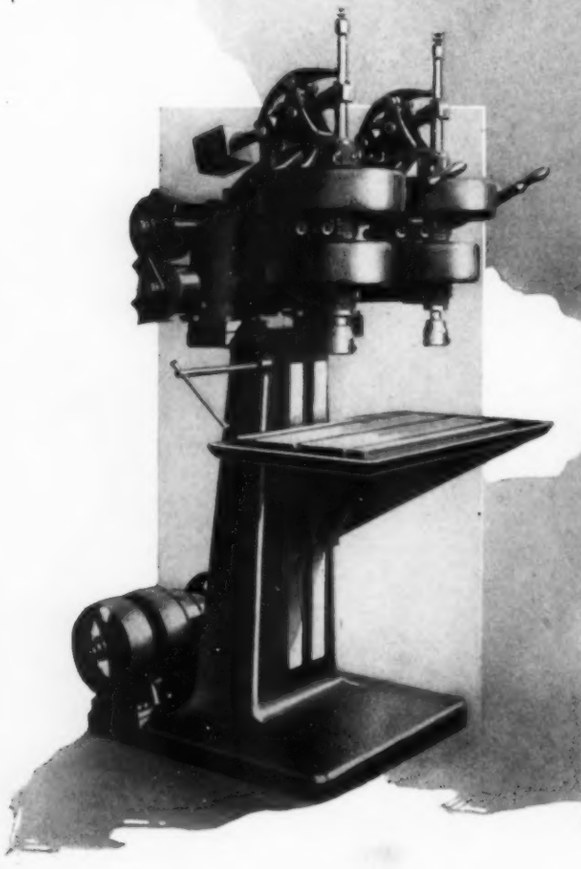


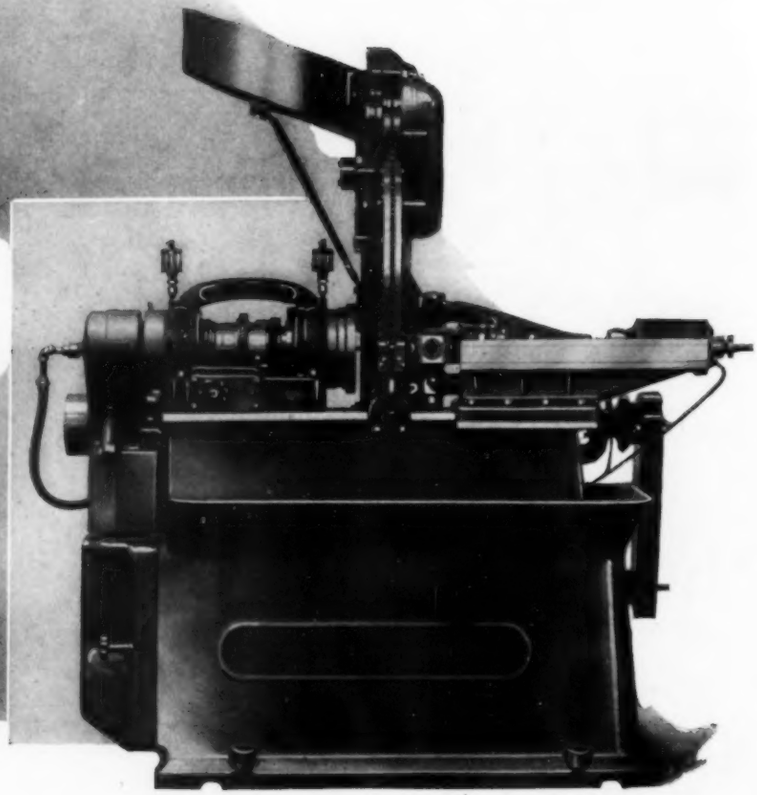


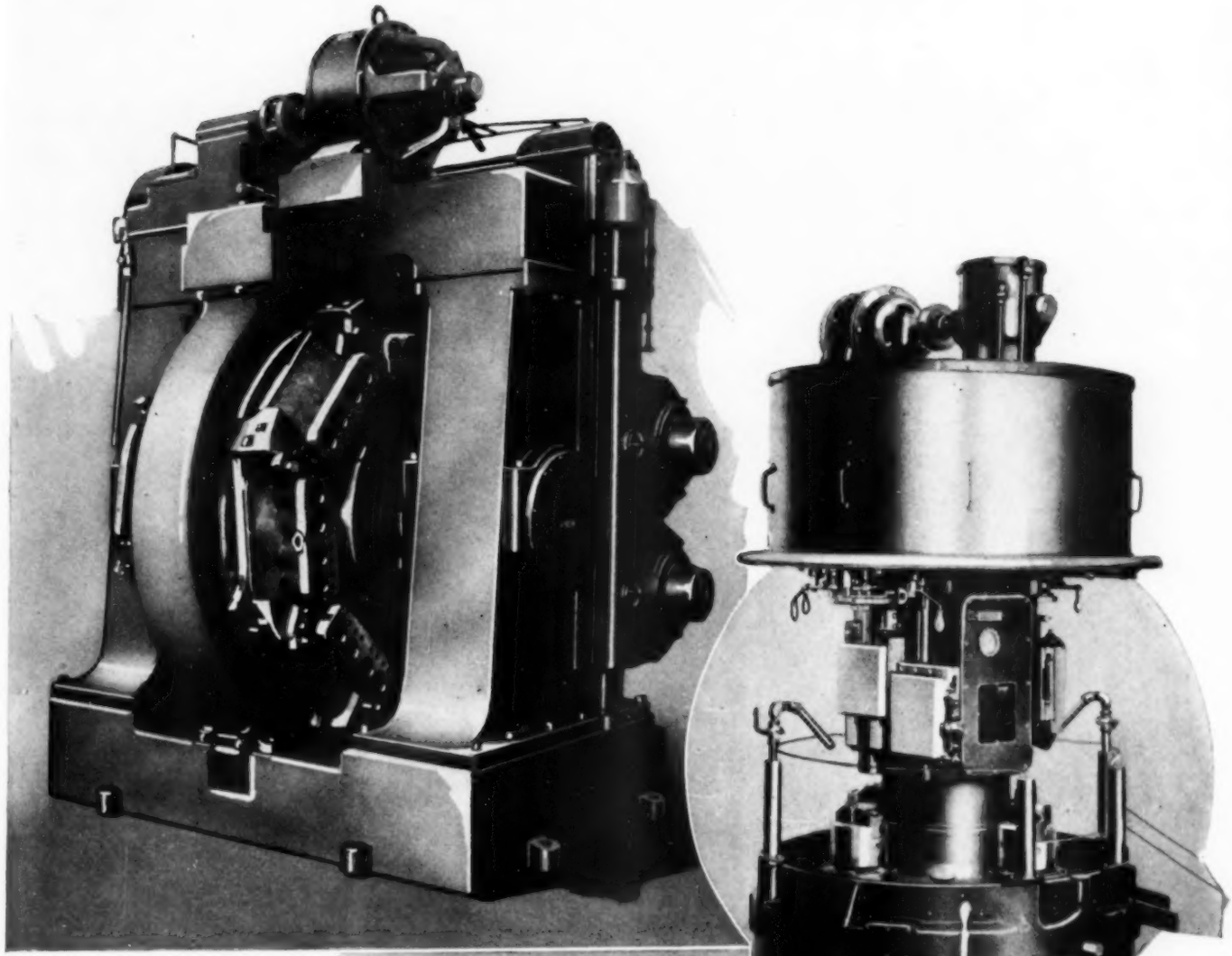


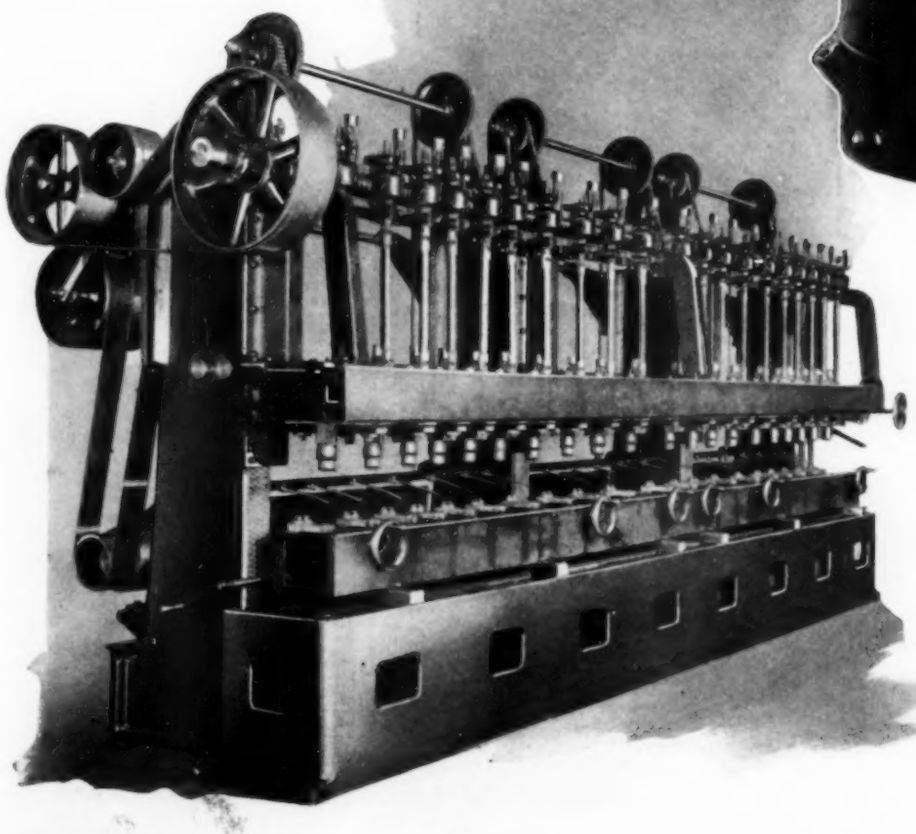
Thread Cutting

Nearly all short threads of fifty years ago were cut by hand with taps and dies. In the case of external threads several passes with the die were necessary. Now we have threading machines of various types including the thread miller. Complete threads are made at one pass and dies are self opening, obviating the necessity of running them back over the threads just cut. Likewise taps over certain sizes are collapsible. Short threads are milled by a hob in one revolution of the work





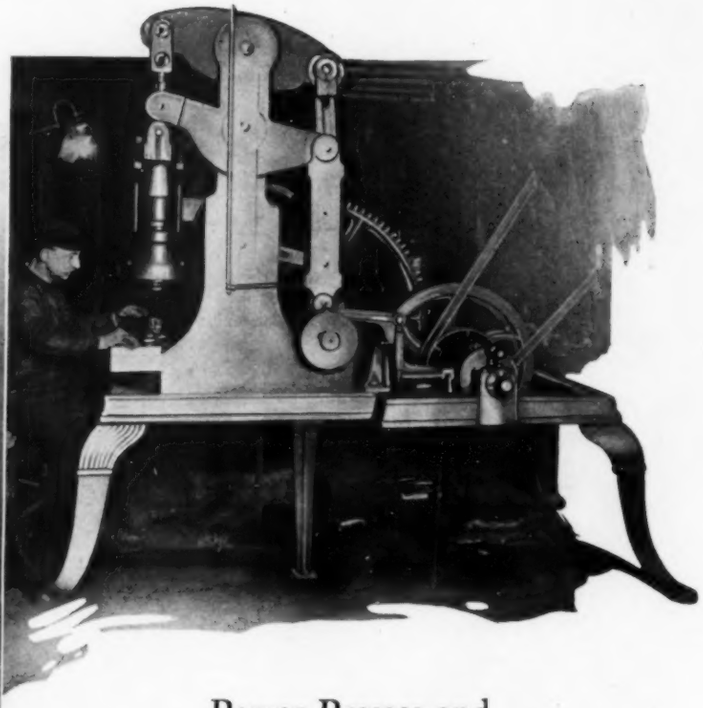




Station-Type Machines

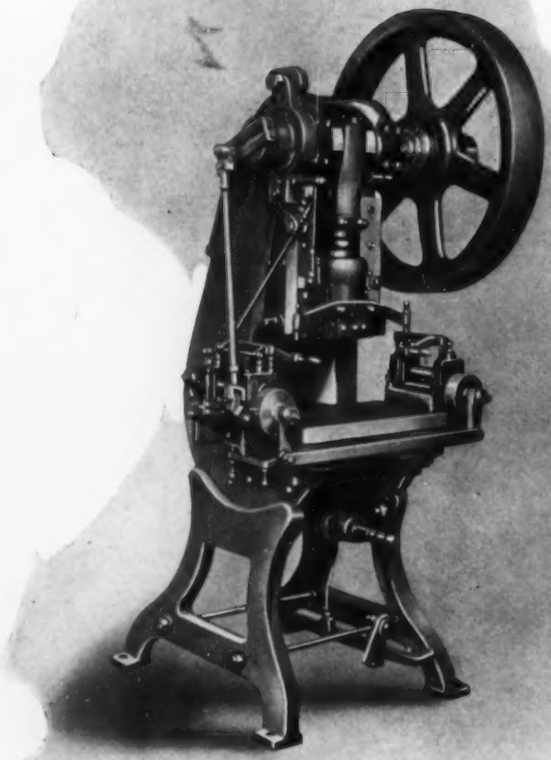
High production of duplicate parts in the automobile plants has brought about the design of multiple station machines in which the work is brought automatically from one operation to another. Examples of these machines are the drum type of continuous milling machine, and the vertical multiple spindle automatic chucking machine. The cylinder borer is representative of the semi-automatic machine of this class

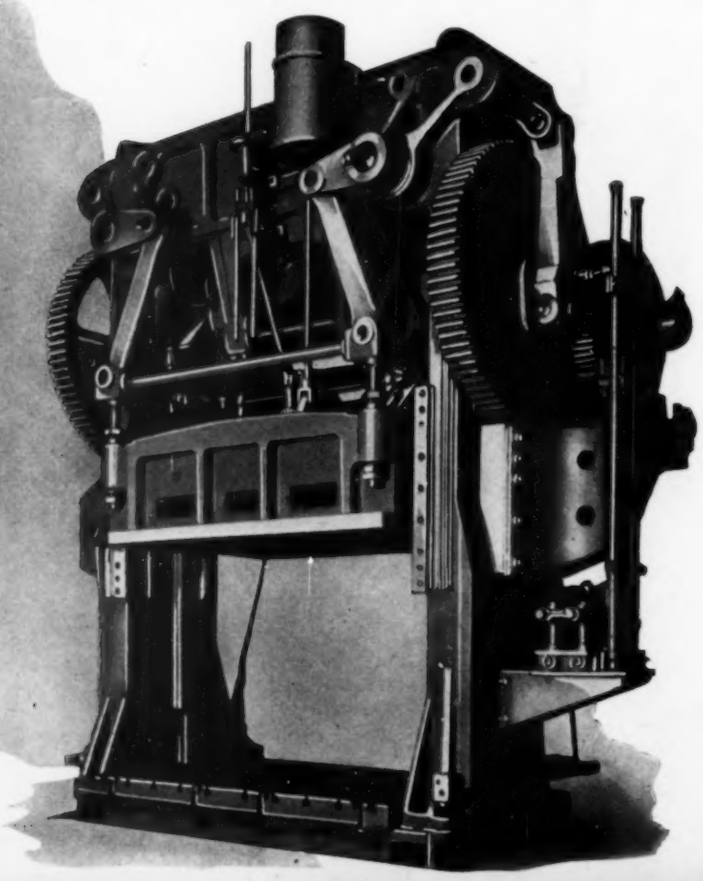
Fifty years of machine tools

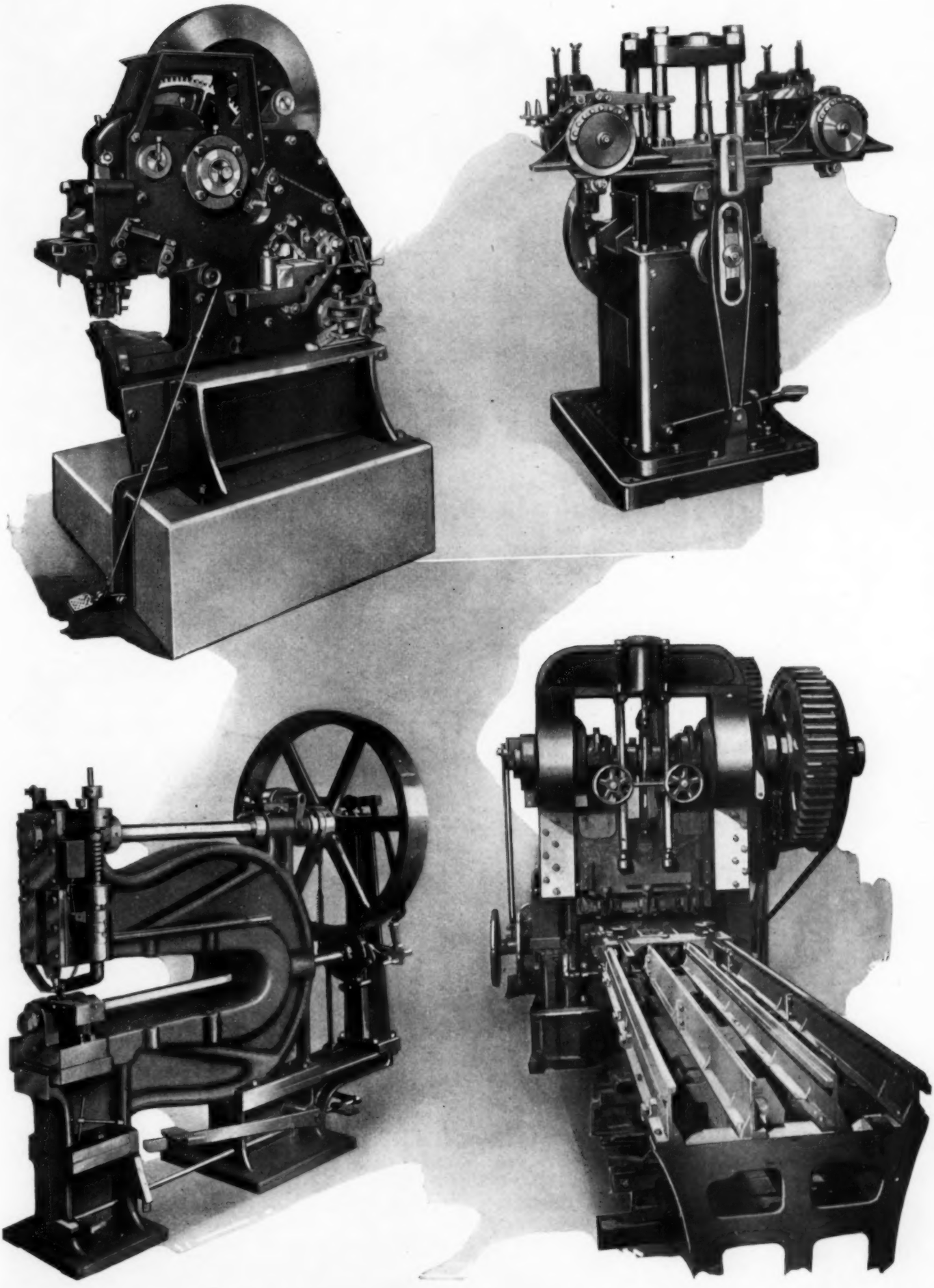


Power Presses and Shearing Machines

The crank press and power presses of 50 years ago showed good design, but in productive capacity and adaptability cannot be compared with the modern power press with automatic feed, or the heavy duty hydraulic presses and automobile body press. The body press shown has a stroke of 33 in. and a bed size of 80x128 in. Modern punch and shear machinery is also illustrated in the pictures of the heavy punch and shear, the sheet metal cutter, the dieing machine, and the spacing punch







Fifty years of machine tools

Forging Machines

The modern board drop hammer is a production machine for turning out large numbers of forgings per hour. The type shown is built in sizes up to 5,000-lb. falling weight. The early upsetting forging machine of 1890 weighed about 32,000 lb. The modern upsetter shown weighs 355,000 pounds

Resumé of the Development of Steel Treating

By J. FLETCHER HARPER
President, American Society for Steel Treating

A RESUME of the development of steel treating permits only a brief discussion of a few of the most outstanding factors which have contributed to the progress of its art and science. That the art of iron and steel making was known by ancient civilization is a certainty. Likewise the art of hardening ferrous materials has been known for ages, and at some periods of civilization it reached a high state of development. According to archeologists and historians, iron was known in Egypt as early as 7000 B.C. The Hittites, a race of people of rather high civilization, worked iron deposits along the Black Sea before the thirteenth century B.C. An arsenal in Assyria (700 B.C.) contained two hundred tons of iron implements. Pliny (23 to 79 A.D.) records that "It is the practice to quench the smaller articles made of iron with oil, lest by being hardened in water they should be rendered brittle."

IN EARLY times the manufacturer of fine steel usually located his works near certain rivers whose waters were thought to impart special properties to steel quenched in them. Thus it was that Damascus and Toledo became famous for their wonderful sword blades at a date long before the Christian era. No doubt the finer art of steel treating may be traced almost directly to the manufacture of damascene steel.

William Gilbert, a celebrated English natural philosopher, discovered in 1600 that when a permanent magnet is heated to redness it loses its magnetism. This discovery, as all students of steel know, was an exceedingly valuable one and one which plays an important role in present-day research into the physics and constitution of steel.

Reaumur, a noted French physicist, published in 1722 his book on the conversion of iron into steel by the cementation process. He investigated the differences between iron and steel and described the annealing of hard iron castings imbedded in iron ore to take away much of their brittleness.

Benjamin Huntsman in 1740 developed the first successful process for the fusion of blister steel on a commercial scale. This development came as a result of an endeavor to obtain a more uniform material for the manufacture of clock springs. It was the first material which combined uniform strength, toughness, hardness, and lightness.

After the invention of the steam engine in 1781 methods of transportation advanced rapidly. With increased westward migration railroads became necessary and the increased demand for transportation of people and commodities resulted in a strong demand for more and better rails. This was one of the prime factors which speeded up production and developed new processes for meeting the demand for a better product.

Superstition and secrecy surrounded the manufacture of steel and its heat-treatment until recent times when such men as Bessemer, Sorby, Hook, Reaumur, and a host of others, began to give to the world the results of their systematic and scientific study of the natural laws governing metals.

While Henry Bessemer was perfecting the pneumatic process of steel making in England, William Kelly in America developed independently this same method of making steel. Bessemer received his first patent covering the invention of the converter in 1856 and in 1861 Charles, William and Frederick Siemens invented and gave to the world the open-hearth regenerative steel melting furnace. The electric furnace method of steel melting was invented in 1878 by Sir William Siemans.

And so we see that the progress in the development of steel and its heat-treatment is to a large degree the history of the activities of the men who made it possible. It is the history of men with curiosity, of men with vision, of men with ideas and ideals.

Prior to the discovery and development of the pneumatic method of manufacturing steel, commonly known as the Bessemer process, steel was manufactured by the cementation process or the crucible process. These former methods were of such a nature that they did not permit of what we know as large-scale production. The crucible method, which is still practiced in the manufacture of high-grade tool steels, is restricted to small batches, whereas the Bessemer method permits of larger batch production in shorter time. The old blister steel method is still practiced but to a very limited degree, having been replaced almost entirely by the newer and faster methods.

THEN came the Siemans-Martin open-hearth method of steel production which has outstripped the Bessemer method until today it holds first place in tonnage steel production of the world. In the last decade of the 19th century, the electric furnace method of making steel was discovered. Many competent men have worked on this phase of steel production and numerous types and kinds of electric melting furnaces have been developed. This method of steel production bids well to hold a very important place in the production world. With constantly decreasing costs for electric power through the use of water power, the electric furnace is making pronounced headway and has come to stay.

As early as 1774, Rinmann, of the University of Sweden, noted that the element carbon had an important effect upon the properties of steel. Later, Vander-

monde, Berthellot and Morge pointed out that the distinguishing thing between iron and steel was the carbon content. From this time on much theorizing was done and by means of the microscope, the discovery of which is credited to Galileo (1564-1642), numerous investigators studied and examined many specimens, and in 1863 Sorby began a systematic study of metals by this means. Since that time the science of metallography has played a most important role in the study and heat-treatment of metals. The literature teems with information obtained through the aid of the microscope. About 1885 microscopic lenses were improved upon whereby the possible magnifications were much increased. With this improvement Sorby discovered something which he could not see at the lower magnifications. The discovery was the constituent which we now know as pearlite. This development came in the last years of the 19th century and at a time when there were ever-increasing demands for better steels. Many investigators were now at work with their microscopes. Osmond, Martens, and Tschernoff contributed largely to this new science of metallography. They identified the various structures that are obtained in steels of varying compositions when subjected to different heat-treatments and these facts form the basis of our modern methods of the heat-treatment of steels.

The work of Sorby was followed by that of Osmond and Martens, each of whom studied materials under the microscope and in varying conditions of heat-treatment. It was realized by these men that through the application of heat the structures of steel could be altered and with altered structures the physical properties changed. The ability to examine a piece of steel under the microscope without having to destroy its anatomy is one of the great features which characterizes this method of examination in lieu of chemical analysis.

The problem of measuring temperatures was a serious one and it was not until Le Chatlier in 1885 perfected the thermoelectric couple that it was possible to measure within narrow limits the temperature of the furnace and the piece of steel being heated. With this device the effect of heat on steel was studied minutely and with the development of the thermoelectric pyrometer manufacturers were provided with a new and powerful aid in their investigations. It is by means of the thermocouple that the effect of various alloying elements on the critical points of steel is determined and it is largely by means of the thermocouple that accurate heat-treatment can be obtained and maintained in actual production.

IN 1880 F. W. Taylor began his studies on shop efficiencies. He set out to increase production and studied the various materials with which a machine shop is furnished both in the form of tools and in material to be machined. This investigation continued for a period of 26 years and in 1906 the large mass of data which had been collected by Taylor and added to by White was made public.

Between 1898 and 1900 one of the most interesting discoveries in metal manufacturing was made. Tools made from chromium and tungsten steels when operated at almost a red heat were able to produce from two to four times the amount of work that the various plain carbon steels could do. This discovery of "high-speed steel" was a momentuous one because it placed demands upon machining equipment with which the equipment of that day was unable to cope. The speed of operation of a lathe, for example, could be much increased and the stresses placed upon these machines were greater than those for which they were designed. This ultimately resulted in the re-designing of practically all machine tools.

About 1890 the bicycle, a new and faster means of transportation, was developed. It was the first example of mass production which required both lightness and strength of construction. The automobile followed the bicycle very closely with ever-increasing demands for mass production and lightness of construction, which resulted in the need for heat-treating various parts that had to be light in weight, small but strong, and capable of withstanding great shocks and hard usage. The manufacturers of steel were forced into conducting research on the properties of materials when alloyed with many of the elements such as nickel, chromium, vanadium, molybdenum, and others. They found that in order that the maximum physical properties may be brought out in steels which were alloyed, it is necessary that they be properly heat-treated. The determination of the proper heat-treatment was of course a tremendous undertaking but was participated in by many investigators, notably the principal steel companies of the world and scientific societies and institutions of learning.

THIS knowledge was valuable when another highly important phase of transportation was discovered—the modern airplane—in which lightness and strength are of paramount importance. The high-powered gasoline engines used in these machines are the result of minute engineering study and design and the parts going into these engines must be made of high-grade alloy steels, most of which are in the heat-treated state. The turnbuckles and landing gears likewise must be constructed of heat-treated alloy steels.

With a knowledge of the proper heat-treatment, the next step in the procedure was the obtaining of suitable heat-treating facilities. In the early days the open-forge fire was used almost entirely, and especially for the heat-treatment of tools.

Then came the small-sized single-batch furnaces for the heat-treating of a small number of parts. Most of these furnaces were of the oil-fired or gas-fired type, but with the increasing demand for quantity production these furnaces were increased in size and efficiency by means of conveyors, pushers, and rotary furnaces. In more recent years the electric heating furnace has been developed in which are embodied all of the features of automatic operation and automatic temperature control for heating. Many of these furnaces are so designed that the raw material is brought to them by means of conveyors and not touched by workmen throughout the entire heat-treating operation.

The art of heat-treatment is playing an increasingly important role in the progress of modern manufacture and one need only look about him and observe the hundreds of highly efficient heat-treating departments which form a major part of every manufactory having to do with the production of steel in its myriad applications and uses in modern civilization to realize that it is of tremendous importance.

Hours and Wages in the Metal Industries

By FRED J. MILLER
Past President
American Society of Mechanical Engineers

THREE distinct groups of people are directly and vitally interested in wages: Those who pay them; those who earn and receive them; and those into whose hands they go in payment for what wage-earners buy. Upon at least one aspect of the wage question all three of these groups are generally agreed, i.e., that high wages for everybody are much better than low wages; for high wages mean prosperity and "good" business—more goods sold; more machinery needed for making the more goods; more machine-tools for making the more machinery; and so on.

Wages were abnormally low when the *American Machinist* was started. Four years earlier the Jay Cooke failure had started a panic which, for severity and long-drawn-out consequent depression, has, I think, never been equaled in this country. The machine-tool business particularly was profoundly affected because at that period it depended, mainly perhaps, upon railroad building and extension. Within five years previous one thousand, seven hundred millions of dollars had been spent in building new railroads, almost entirely on credit and largely through unsettled regions where compensating revenues could not be expected for many years. Much of the money obtained by selling bonds for this (at that time) tremendous and extravagant construction had gone into the purchase of shop equipment for railroads and for makers of railroad supplies. Consequently, when the crash came machinery builders, and especially machine-tool builders, felt it severely.

AND so, in 1877 there was much unemployment and wages were abnormally low. In June of that year the *American Machinist* published the names and the wages paid by some seventeen employers of machinists, among them three important Eastern railroad companies. Two of these, the New York Central and the New Haven, paid the same wages—10.5 to 21.25 cents per hour. The Lackawanna was paying at the same time 18 to 24 cents per hour, and the New York elevated roads 20 to 30 cents. Perhaps, in the case of the two roads reporting such low wages, some of the men were classed as machinists just because they worked in machine shops. The high wages of the elevated roads are probably to be explained by the high cost of living in New York City.

At that time, Paterson, N. J., was a locomotive-building center and wages at the Danforth Locomotive and Machine Co. shops were 15 to 18 cents per hour; at the Grant Locomotive Works they were from 16 to 18 cents. The Hendey Machine Co., then located at Wolcottville, Conn., was paying from 17.5 to 30 cents, with a stated average of 22.5 cents, while the Stiles & Parker Press Co., Middletown, Conn., paid 20 to 30 cents. At Massillon, Ohio, the average pay of machinists was slightly over 19 cents.

The South, then as now, paid considerably lower rates than were paid elsewhere, and California paid considerably higher. Aside from these two extremes the figures given seem to be fairly representative of the country, though S. Ashton Hand, who was in the gage business in Philadelphia at that time, states that wages there were from $2.50 for ordinary, to $3.50 for exceptionally good machinists, per 10-hr. day.

THE recovery of good business, beginning in the Fall of 1879, was so rapid that wages soon followed the upward movement, and in the Spring of 1880 were, in general, about 20 to 25 per cent higher than in 1878.

Coming now to our own times, the latest figures available were published this year by the U. S. Department of Labor, although the study on which they are based was made in 1925. The highest average wage for toolmakers, in any state, is given as 91.5 cents, the average for the country as about 73 cents. For machinists, the highest average wage in any state is given as 83.1 cents, and the average for the country as 70.2 cents.

It is apparent that per-hour wages of machinists and toolmakers have more than trebled within the 50-year period, though in general the straight ten-hour day has been shortened so that daily wages are not now ten times hourly wages as they were fifty years ago. What are called "real wages," i.e., wages measured by what they can buy, have also increased, but certainly they have not trebled; although in other trades they have done that or more, due to special causes and, of course, it is the relation between wage figures and the cost of necessary things that most concerns the wage earner.

No doubt the increase that has taken place is due largely to the fact that labor costs of machine shop products have become relatively less important than they were fifty years ago, while costs of material and operating expense have relatively increased. This is a natural result of a number of contributing causes, such as improved management methods; improved machinery and tools; high-speed steel; and automatic instead of hand-operated machines. All these cost more and add to operating expense because operating expense includes cost of power, light, heating, supplies, insurance, depreciation by wear, and obsolescence; besides, usually, increased tooling and maintenance cost. All these are, of course, justified or they would be avoided, as in fact they are avoided, more or less, by the reactionaries and the incompetents. In other words, modern developments have made wage rates relatively less important, because of greater production per man hour and increased relative operating costs.

Gear Design and Manufacture 1877 and 1927

By EARLE BUCKINGHAM
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AFTER studying through many text books, engineer's handbooks, technical publications, trade catalogues, etc., published prior to 1880 in the attempt to re-create an atmosphere of fifty years ago as regards the state of the art of gear design and manufacture, the writer found himself compelled to admit the truth of the statement made by an engineer after reading the memoirs of Leonardo da Vinci: "Practically all of the discoveries and inventions of the ancients were stolen from us moderns!"

Broadly speaking, the major advance in this art during the past fifty years has been the refinement of manufacturing processes and the product. Fifty years ago, the cycloidal form was almost universally used as a gear tooth profile—today it is the involute form. Then, a large percentage of the tooth shapes were formed by hand, often from templates. Cast teeth were commonly used on all large wheels except where mortice wheels with wooden cogs were employed. Today, the cut gear is the standard, although cast teeth are still to be found in many places.

In order to bring out the nature and extent of the advance in this art, a brief summary of the general practice of fifty years ago and of today will be given.

In 1877, the cycloidal form of tooth was the one generally employed although there were some strong advocates of the involute form. At this time the standardization of various machine elements was receiving serious attention. Considerable progress in this direction had been made with screw threads, and attention was directed toward the establishment of standard tooth proportions for gears.

FROM "Designing and Construction of Machine Gearing," by F. H. Joynson, published in 1868, we obtain the following:

"The breadth to be twice the pitch in all calculations for strength; any extra breadth is of no further use except for extending the bearing surface and lessening the wear. Practically, three times the pitch is the utmost limit."

It should be appreciated that the foregoing applied to cast teeth, and that experience with such gears showed no increase in strength with an increase in face because the imperfections in the teeth did not permit a very long bearing. Today, we often have a very similar difficulty with the bearing on the teeth of bevel gears.

Unwin makes the following remarks about the involute form:

"Involute teeth have two remarkable properties. All involute wheels, whose teeth have the same pitch and the same obliquity of the line of contact, work well together. A pair of involute wheels may be drawn a little further apart, without the accuracy of action being impaired, though the arc of contact is diminished. With the angle of obliquity given above (15½ deg.) the smallest number of teeth in an involute wheel should be twenty-five. With fewer teeth the arc of contact is too small. The obliquity of action is ordinarily alleged as a serious objection to involute wheels. Its importance has perhaps been overrated."

Professor Willis' "Principles of Mechanism," published about 1850, devotes considerable space to the involute form and suggests tooth forms for pinions with increased addenda. In this book, and in all others on this subject, tables of constants for laying out tooth forms, or Odontographs, are given. These indicate the importance of the pattern-maker to gear production at this time. In fact, one of the strongest arguments for the use of the involute form was that these forms could be shaped with a flat chisel or plane while the shaping of cycloidal forms required the use of a gouge.

MANY different formulas for determining the strength of gear teeth were used. Quoting again from Unwin:

"In determining the strength of wheel teeth, it is not necessary to take into account their curved form. It is sufficiently accurate to treat the tooth as a rectangular cantilever of uniform thickness equal to the thickness of the actual tooth at the pitch line.

"At high speeds the influence of shocks and vibrations becomes more serious. Reuleaux has proposed to allow for this by making the value of the stress '*f*' decrease inversely as the cube root of the velocity of the pitch line. (In ft. per sec.) Then for cast iron

$$f = \frac{10{,}000}{\sqrt[3]{V}}$$

For mill gearing, we find but three materials generally mentioned for the gear wheels; namely, cast iron, brass, and hard wood. Cut gears were used to a limited extent, but their use did not seem to be very general.

In "Molesworth's Pocket Book of Engineering Formulæ," published in 1876, we find only the cycloidal form mentioned. The following has been abstracted from this hand book:

Strength of Teeth of Wheels (Cast Iron)

B = Breadth of teeth in inches,
P = Pitch of teeth in inches,
V = Velocity of pitch line in feet per second,

H = Actual horsepower which may be transmitted by wheel.

$$H = 0.06\,P^2VB$$

Proportions of Teeth of Wheels

From pitch line to top of tooth	0.33P
Total depth of tooth	0.75P
Thickness of tooth on pitch line	0.45P
Thickness of rim of wheel	0.45P
Ordinary width of teeth in small pitches	2.0P
In large	3.0P

"Mortice wheels to be wider than iron wheels by twice the thickness of the rim or by pitch times 0.9; their rim to be double the thickness of that of iron wheels.

"In making a set of wheels, the teeth of all wheels of the same pitch that may be required to work together should be generated by the same rolling circle.

"In the workshop the curves of the teeth are struck out by rolling the template of the generating or rolling circle on a template corresponding with the pitch line. A scriber or pencil on the periphery of the generating circle marking out the required curve.

Pitches of Equivalent Strength for the Teeth of Wheels in Different Materials

Pitch for cast iron	1.00
Pitch for brass	1.12
Pitch for hard wood	1.26

IN 1877, the most common method used for the production of gears was by casting. Some special gear cutting machines had appeared on the market, and dividing heads for use on planers, lathes, and milling machines were available. Profile-relieved milling cutters had not yet been developed so that the formed milling cutters employed for milling the teeth were ground by hand to fit a templet whenever they were resharpened.

Two methods were used to make the molds for the cast gears: first, using a complete pattern; and second, machine molding where the rim was molded from a pattern of two or three teeth which was indexed by the wheel molding machine. Very small wheels were cast with a blank rim and the teeth were cut in a wheel cutting machine. Unwin states that the machine-molded gears were the most accurate, and that machine-cut gears were expensive and the teeth were generally inferior in form to those of molded wheels.

The possibilities of generating the tooth forms with a tool of basic rack form were not unknown and this method was receiving considération and had been used experimentally, but had not come into general use.

Commenting on the methods of making gears in 1877, Mr. Wilfrid Lewis says:

"Going back to my early days at Wm. Sellers & Co. they had then a very complete automatic gear cutter for spur and bevel gears and a cutter forming machine to make milling cutters similar to the standard cutters introduced by Brown & Sharpe. These cutters were made to approximate the true epicycloidal and hypocycloidal curves for face and flank by means of circular arcs, and about 1878 or '79 after serving three years as a machinist, I undertook to redesign that cutter forming machine, so as to produce the proper rolled curves instead of circular approximations. The reconstructed machine was successful, but it had not been long in use before the cycloidal form of tooth began to be supplanted by the involute, and another change was made in it to produce involute instead of cycloidal cutters. In this way the machine was very much simplified and the cutters were better liked because they cut more freely. Cycloidal cutters always tended to drag at the pitch line, where the tangent lines were radial, and it was difficult to cut freely especially when the number of teeth was high.

"At that time, in the early '80's, bevel gears were cut with radial flanks and cylindrical faces. Two cuts were taken to form the wedge-shaped space between adjacent flanks, and then a machine operator of long and varied experience, who was reputed to have a good eye for shapes, selected and set the cutter for topping off the bevel teeth, which were sometimes perfected by filing and fitting in place."

TODAY, the involute form is the one most widely used as a gear tooth profile. The composite form, consisting of a combination of involute and cycloidal curves, is also widely used, particularly for form milled gears. The tooth proportions have become standardized for practically all general-purpose gears, although considerable attention is again being given to special proportions for critical gear drives. A much greater variety of materials is now employed in the construction of gears, and much heavier loads at much higher pitch line velocities are now being transmitted by gears. Fifty years ago, the main sources of power for the machine shop were low speed water wheels and steam engines. Today we have higher speed water turbines and steam engines, electric motors, oil and gas engines, and high speed steam turbines. The tendency today is toward higher speed, greater power, and smaller bulk of the prime movers which in turn makes more exacting demands on the performance of gears and other power transmitting equipment.

Helical and herringbone gears have also come into extensive use with the development of suitable means of production. Gear teeth of this type did not lend themselves readily to production by casting.

The Lewis Equation has been widely accepted for the determination of the power rating of gears, yet the velocity factors which are generally used to determine the safe stress at speed are those which were used fifty years ago, and which were deduced from experience with cast teeth.

The great majority of commercial gears today are cut gears. For their production we have a choice of gear milling machines with profile-relieved formed milling cutters, or any of a large variety of generating machines using hobs, pinion-shaped cutters, or rack-shaped cutters. Gear tooth grinding machines also are now on the market which will finish the gear tooth profiles after hardening.

In brief, as stated before, the progress of this art during the last fifty years has been that of refinement of manufacturing processes which has in its turn been reflected in much greater accuracy of the product. Greater accuracy has brought with it longer life, greater strength and the smoother, quieter operation so necessary in many modern gear applications.

Fundamentals of Industrial Procedure

By F. W. SHIBLEY
Vice-President, Bankers Trust Company

THERE are in this country today certain industrial corporations whose principles of business and whose ideas of service permeate the thought of people generally. Outstanding financial success has been attained by them. Quality, management, efficiency and service are words of concrete significance with them. We in the banks have observed the growth and progress of these corporations. We have compared their systems of operation with the systems of former days and which are still adhered to by many enterprises whose managements are complacent and inert.

Recognizing that knowledge must be acquired along the natural lines of actual perception and experience these leaders in industry realize that they must ascertain and acquire facts on which to base conclusions. They know that there has been too much value placed upon opinion as the basis of business management and too little gathering of facts. Therefore, the fundamental of their creed is to dig down through the soil to a rock foundation on which to construct their industries.

This bed rock is a comprehensive knowledge of markets, of consumer capacity to purchase and of consumer demand. In their hands market study has become a practical science.

Possessed of a knowledge of markets gained through diligent, protracted investigation and studious, laborious inquiry they are in a position to make an intelligent forecast of income from probable sales.

On the forecast arrived at through organized forethought they base the production schedule which of necessity compels the co-ordination of plant facilities and working capital requirements. The central idea of this procedure is to make only what they have good reason to believe they can sell, not to make with the hope they can sell. Operating expenses are then budgeted in detail to conform with the income forecast so that the required profit shall be obtained.

THE next process is to control operating costs through monthly revision and correction of both the sales estimate and the sales expense, thus creeping into the future, thoughtfully feeling the way, setting up a new month's forecast as an old month expires, watching the sales trend, taking up the slack of a product failing to excite consumer demand by stimulating an increased demand for the products that sell as anticipated, and by inciting demand through new styles.

The problem of management is to attain or even exceed if possible the forecast, and the operations of the twelve monthly periods must be molded to that end.

Such an accomplishment demands executive management of exceptional quality and a system of control, for few men possess the capacity of controlling operations with scientific accuracy without a system.

The modern business budget provides all the essentials of control demanded by such a system. It lends itself to comparative analysis. It reveals not only the units but the electrons of a business. It brings out into the spot light those miserable little foxes of industry which spoil the vines. It reveals forethought in department heads or the lack of forethought. It makes every appropriated extravagance stand forth as a sore thumb. It is a compress in which operating costs are squeezed until they fit into the percentage spaces allotted to them.

BUDGETARY control lays the month's business on the operating table for dissection and analysis. Chronic disorders cannot obtain foothold where it rules. It is the enemy of waste but withal it is a very dainty piece of mechanism like a particularly fine watch made by a highly skilled workman. It must not be dropped on the floor or thrown about. It required exceptional ability to conceive and make it. It demands exceptional ability on the part of him who shall obtain the best results from its use.

Thus we come to management, the all important element in the industrial structure which has made the corporations previously referred to so successful. Management is the god in the business machine. The great executive is a thinker.

The executives of the successful American industrial corporations whom I have known are forever studying their problems and the more they contemplate these problems the more certain they become that they are only human beings limited both as to space and time and that if they are to manage wisely and successfully they must delegate authority and demand responsibility as the price of such authority even as they are responsible for the authority given them by their stockholders and directors.

Thus has arisen a system of centralized executive management control with a delegated divisional or departmental authority with responsibility.

And so authority with responsibility proceeds through delegation all down the line resulting in leaving the chief executive free from detail to think out and think through the new problems which constantly arise having to do chiefly with the future. This results in making a real man of each divisional or departmental head for, under this system, each such man must make decisions within his province and it is the making of decisions that makes executives.

Such briefly describes this system of industrial management and control which has made American industry so outstandingly successful.

Gaging, Inspection and Mass Production

By COL. E. C. PECK
Chairman, National Screw Thread Commission

IN BARGAINING for a commodity, it is necessary to have a standard acceptable to both buyer and seller to determine whether or not the commodity is understood by both and the bargain carried out. Ancient tribes, states and countries used gages originating with themselves and probably the tribe or state doing the most trading with the neighboring countries succeeded in establishing their gages in other countries and hence the most used gages were handed down to us.

Because of the customs and habits of the people of various countries, no one set of gages or standards was so superior to all others that it could be acceptable to all. This same condition exists today, hence the heterogeneous collection of gages and standards in use over the world at the present time. International standards would be of immense economic value if they could be arrived at voluntarily, but this implies that the proposed standard would have the merit to win its way with the people and economically compensate them for the expense of changing. Such a valuable standard has not as yet been proposed.

Standardizing, gaging and inspection grew slowly and gradually as civilization advanced and manufacturing came into existence. Two centuries ago advanced thinkers began to get a glimmer of the advantages of more uniformity in the parts of a mechanism. In 1717 some form of interchangeable manufacture was attempted in France but it was unsuccessful. It was again tried in 1785 and again failed.

Great impetus was given the whole subject in 1798 when Eli Whitney, of cotton gin fame, took and completed a contract for ten thousand muskets for the United States Government. The parts of these guns were interchangeable. English and French ordnance officers ridiculed and criticized Whitney's ideas to such an extent that Congress became alarmed at the money being used for the purpose. Whitney went to Washington with ten guns and distributing the parts on the floor, repeatedly assembled ten guns from the parts, and they all operated properly. This remarkable achievement astonished every one and it is believed to be the first successful interchangeable manufacture of accurate work. In 1808 Simeon North accomplished a like feat on pistols for the government.

Gaging and inspection is the process by which the parts of a mechanism are accepted, so that they will assemble without fitting and function properly. This is the most exacting requirement of gaging and inspection, although many units are rigidly gaged and inspected which are not assembled at all in a mechanism.

There are several degrees of interchangeability. Strict interchangeability consists in making the corresponding parts of a mechanism so uniform in size and contour that each part will fit and function properly in any one of the whole number of mechanisms, no matter when or where it was made. It will be noted that this means that each part of a mechanism of a given model will fit any of the mechanisms of the same model regardless of the lot to which it belongs or the year in which it is made.

Some interchangeability consists in making the parts interchangeable for the series only. In this kind of interchangeable manufacture, any slight change in the model is made at the end of a series and replacements or repairs are furnished to fit by referring to the series number.

Before the modern accurate machinery was available, it was necessary to finish most work by hand, and to make it uniform required great skill. To take advantage of the work of less skillful workmen template filing was resorted to in order to get uniformity. For example, gun and pistol parts would have the holes drilled and reamed in a jig or fixture and then the contour finishing was done by putting these pieces into a template jig provided with pins to fit the holes and locate the pieces in relation to the contour of the template. The outside of the template or jig was the shape required and the workman would file down to this hardened template, which controlled the shape. Many ingenious devices and schemes were used to facilitate the duplication of parts and great skill was developed in the workmen.

THE introduction of modern machinery and new methods has improved the product to such an extent that hand work has been nearly entirely done away with. The demand for manufactured articles has increased to such an extent that large quantities can be made at one time. This supplanting of hand labor by machinery is generally referred to as the period of "Mechanical Revolution" and the exact date is not fixed so far as the writer knows.

Refinement of machinery, methods, tools and product has changed manufacturing quite materially in the last fifty years. Formerly, machinists were all-around men capable of doing all the work connected with any piece of machinery. It was not uncommon for several men or even one man to do all the work on a mechanism. The first drift away from this was for workmen to specialize so that machinists became known as lathe, planer, shaper or milling machine hands. Formerly, the toolmaker as the name indicated was a skilled machinist who could make any of the tools a machinist required, and he usually did make many of the drills, reamers and cutters. When specialization began, the names machinist and toolmaker had a definite meaning, but today it is difficult to

define them. Generally speaking, machinists are operators of the kind of machines usually belonging to the machinist trade, while toolmakers are the old time, all-around machinists with the required skill to make jigs, fixtures, etc. The tools unless very special are made by manufacturers who have specialized in the art of tool making and who have a special equipment suited to make tools better and cheaper than a toolmaker could. The gagemaker now takes the place of the old time toolmaker in a large measure, that is, he is usually the most skillful of the workmen in an industry, and he makes the really fine work that is required.

THE combination of all these changes with increased demand has brought about the system of manufacture known today as "mass production." This system implies the repetition manufacture of a large number of identical pieces by specialized machinery, tools and fixtures. Next to economy, the principal object sought is the identity of size and contour coupled with quality of work.

Standardization, gaging and inspection under "mass production" has so changed a large part of our manufacturing that complete mechanisms of a high mechanical order can be made, by "unskilled" but properly trained help, that in every way equal those made by the highly skilled help of fifty years ago.

As before stated, "mass production" is for the purpose of economy and when properly done and accompanied by gaging and inspection, it produces interchangeable work. Thus a two-fold economy is affected: first, that of obtaining accurate component parts at a low labor cost by so-called "unskilled" but highly trained help; second, the low cost of assembly due to the parts being truly interchangeable.

The changes in manufacture which have been noted bring us up to the outbreak of the World War. The enormous demand for all kinds of manufactured material on a scale never before dreamed of, brought about intensive effort and thought which still further advanced manufacturing in general.

Up to this period, interchangeable manufacture was practically confined to single shops; that is, many shops were making work that was interchangeable in its own particular plant, but scarcely any of it would interchange with that of another plant. This is not strange, because there was little demand for such a procedure except in a limited number of articles.

The immense amount of munitions required by our Allies and the U. S. Government soon developed the fact that if we were to get anywhere with the project on hand, universal interchangeability in at least some respects must be had at once. It should be borne in mind that while the Springfield Armory had made excellent rifles on an interchangeable plan for years, the interchangeability was in this Armory only. If other gun manufacturers were to make rifles so that any large part of the components would interchange, they must at least have a duplicate set of the master gages used by Springfield Armory. It could hardly be assumed that the machinery, equipment and system of manufacture would be the same as that of the Armory, but with a full set of identical master gages, sufficient interchangeability for war purposes might be attained.

The Government soon found that while this single-shop interchangeability would do for some of the work required, full advantage could not be taken of all the manufacturing facilities of the country. That is, the manufacturing operations were not so balanced but what there would be idle equipment in a majority of shops if a shop were given a complete unit. If complete units were not let to one shop then universal interchangeability must be had in these shops or the munitions would not assemble or would fail to function.

Manufacturers who could each make interchangeable fits in their own shops could not agree on a system of gaging, inspection or fits. This country has had the U. S. Thread System since 1864 but at the outbreak of the war the Government could not obtain screws and nuts made to this system by different makers that would go together dependably. There were at least five different actual sizes for 1-in. x 8-thread taps, all supposed to be U. S. Standard. This was not so bad as it sounds, because individual manufacturers usually confined their wants to one tap and one screwmaker, and as long as the bolt maker knew whose tap was used there was not much trouble. The Government, however, had to buy from all of them and hence the trouble.

It is quite obvious that with the U. S. Standard fixed by law, the only difference would be in the tolerance and shop practice of the maker. The same is true of cylindrical and sliding fits—we had standards of measurement but not of tolerance and shop practice.

Another serious condition at this time was the variation in the actual sizes of the so-called standards. Some of this trouble was due to wear, some to change by age and some to the fact that they never were right.

THE first step for the Government then was to bring these existing conditions into as much harmony as possible with the least upsetting of the practice and in the quickest time. Accordingly the Bureau of Standards at Washington was made inspector of the dimensions of all gages for the Ordnance Department of the Army and at once corrected the condition of variation in standard measurements. As far as possible without unduly holding up production, the system of gaging and inspection used by the Ordnance Department of the Army was built up and when it was used as intended universal interchangeability resulted.

This universal interchangeability demands:

(a) Uniform system of tolerances and allowances.

(b) Uniform or correct standards of measurement.

(c) Uniform system of gaging and inspection.

(d) Specifications that can have only one meaning and call for requirements in known measurable terms.

The troubles encountered and the lessons taught by the manufacture of war material have led to more standardization than the world has previously known. It is now possible to have universal interchangeability in machine fits and screw thread product economically. The standards for these are available to all and in case of another crisis manufacturers will all be able to talk the same language.

The period of the war will mark another distinct step forward in mass production, gaging and inspection, because a large number of manufacturers became familiar with the principles and methods involved, who would otherwise never have had any experience.

Planning and Scheduling for Manufacturing

By WALLACE CLARK
Consulting Management Engineer

THE task of planning and scheduling the work for a manufacturing plant has become one of the most important and difficult problems which confronts the modern manager. It is so important that when a new plant is to be erected the method of scheduling work must be decided before the architect begins to draw the plans for the buildings.

Fifty years ago the scheduling of work through a machine shop was not a problem which required much attention. Most of the workmen were skilled, usually performing several operations on one piece of metal and requiring comparatively little instruction or supervision. The scheduling was therefore rather simple and could be kept in the mind of one man. The tremendous increase in volume of product during the last half century has caused a division of labor among workmen which has multiplied the number of times material changes hands. As a result the worman's task now requires less attention and knowledge, while the manager's task is infinitely more difficult.

The various methods of scheduling materials for the sake of convenience may be divided into two types:

1. The mechanical schedule.
2. The reserved-time schedule.

In a plant which is built around a moving assembly the operations of assembling are subdivided until they require approximately equal amounts of time. The length of the moving platform or belt and the rate at which it moves are then determined and the number of feet which this belt moves per minute becomes the master schedule of the plant. The rate of production per hour or per day for every department is thus set mechanically and the task of the Planning Department consists mainly in foreseeing and preventing interruptions.

ANOTHER example of mechanical schedule is found in plants where machines are located according to operations on a standardized product. These operations are so divided that the production of the various machines is equal and the material can therefore flow through all of the machines in the group at the same speed.

This mechanical type of scheduling usually entails a heavy investment in material handling equipment or in special machinery and is therefore economical only in cases where the product is thoroughly standardized and is limited to a few varities which are manufactured in large quantities. The cost in wages and salaries of this type of scheduling is very low because it requires only a few men whose chief duty it is to watch the hourly product and to supply the necessary executive action to prevent its stopping.

In the second type of scheduling the necessary time is reserved on the various machines which are to do work on a certain lot of parts, so that when the material is released from the storeroom it will move through the shop at a definite rate of speed and be ready for delivery on a predetermined date. Scheduling of this kind is used in plants that manufacture diversified products of which the volume is not sufficiently large to make mechanical scheduling economical.

IT IS obvious that such scheduling is far more difficult than the mechanical type and many kinds of technic have been developed to handle this problem. The Gantt Method of scheduling diversified work is probably the most effective and economical. It may be called a decentralized method of scheduling, for each department plans its own work one day in advance and the central planning department does the scheduling necessary to coordinate the work of the various departments in the plant.

No technic of planning or scheduling can be effective unless there is a clear division of responsibility between the various parts of the management. Usually the duties of these divisions of the management are as follows:

The Engineering Department decides what material is to be used and what operations are to be done on it in order to turn out a product of the desired quality.

The Planning Department handles all contact with the Sales Department and agrees with it as to the sequence in which orders are to be put through the plant. It then transmits to each foreman instructions as to materials and operations as specified by the Engineering Department and definite information as to the sequence of the orders in his department.

The Superintendent provides the necessary workers and machines and through his foremen produces goods of the quality specified by the Engineering Department and within the time allowed by the Planning Department.

The introduction of mechanical scheduling, and the improvements in the technic of reserved-time planning, have had a profound effect on metal-working industries. The predetermination of the rate of flow of work through a plant and the concentration of executive attention on maintaining that rate have reduced production time far below former standards. As a result, there has been a decrease in inventories of raw materials, work in process and finished goods, and the ratio of production to investment in machinery and buildings has greatly improved.

This modern technic of planning and scheduling deserves at least some share of the credit for our present prosperity, since it has brought about a more rapid turnover of investment than was considered possible a few years ago.

Time and Motion Study Developments

By LILLIAN M. GILBRETH

OBSERVING how long it takes to do work and by what method the work is done were probably activities of primitive man. Certainly in the oldest records on ancient monuments we see the gang bosses watching their men, to see that the work was done in the proper time and by the proper method. Time study as we know it, as a part of scientific management, started with Frederick W. Taylor, and is, in his own definition, "The art of finding out how long it takes to do work." Motion study, similarly, found its first articulate expression in the work of Frank B. Gilbreth, and is defined, in his words, as "The science of finding The One Best Way To Do Work," meaning by this the application of measurement to determine the best method, given the best available worker, surroundings, equipment and tools.

There is no inherent conflict between time study and motion study; each grew up to meet a real need. Taylor realized that men were not accomplishing what they could and should, largely because of reasons beyond their control, and desired to discover how long it takes to do work, and what the conditions are under which one can expect workers to do an adequate amount of work continuously and thrive. Gilbreth, from his first day in work, noted that variation in method meant variation in result, both as to amount of output and fatigue, and looked for that method, which, because it demanded least effort and fatigue brought largest results in output at the least expenditure of energy.

Gilbreth and Taylor each recognized the value of the work of the other. Gilbreth added the time element to his records, while Taylor put increasing emphasis on the necessity of standardizing the method if the times were to stand as valid.

MOTION study developed technique along two lines. The micromotion method recorded both times and motions on a motion picture film, a fast moving clock being photographed in the field of the activity, which was recorded against a cross-sectioned background. By means of photographing a line of light made by attaching a small electric bulb to the moving part of the machine or man being photographed, and introducing a controlled interrupter, the cyclegraph method recorded the path of motion, time, relative time, speed, relative speed and every other desired characteristic.

Time study continued to use the same technique relying on developing skill in the use of the devices and mathematical formulas.

During the first few years that the two methods were working side by side in industry there was much, and at times serious, controversy as to the uses of each, a controversy finally settled by recognizing the limitations of each method and directing its use to conditions for which it was best suited. More recently, partly because of the passing of the pioneers and the feeling that controversy should lapse, and partly because of the necessity for integrating the various phases of industrial development, the controversy has lapsed. Both time study, in its older sense of stop-watch time study, and motion study, in the sense of micromotion study, are being applied in many industries, and in some plants the two methods are both being applied, with increasing success. The sharp distinction between the two seems to be disappearing.

THE technique is developing and is being evaluated in the light of the needs, immediate and ultimate. Much valuable motion study is being done with no devices but the process chart, which visualizes the operations and suggests savings. Much valuable time study is being done with no equipment but an ordinary clock or watch, or perhaps only by counting to determine roughly the time consumed, and observing changes that would reduce the time. On the other hand, therblig study, breaking activity down into the elements of motions, is increasing, and micromotion films are becoming a recognized part of the equipment of many methods departments.

There are many more people trained to make such studies than there were even a few years ago. Consultants are training such men in plants, stores and offices. Many industries are supplementing such work by sending their engineers, well grounded in the methods and needs of their industries, to be trained in the technique of recording and of teaching better methods. Colleges are including such work in their curricula.

Starting as they did in production work, such studies have spread to selling and to office work. And the results are proving not only directly serviceable in the fields where they are undertaken, but also in locating smaller and smaller serviceable motion units that can be transferred in the field and to other fields.

Perhaps most significant of all is the fact that time and motion study is being now considered as an integral part of progressive management everywhere. Whether that management is lined up under "Scientific Management" or not, it considers job analysis and personality analysis fundamental, and time and motion study are the tools of both.

The future looks very promising. Accurate measurement must always be in some respects a slow and painstaking job, but the results are cumulative, and the fact that they are proving themselves serviceable and extremely practical will make them inevitably an integral part of the campaign against waste, which is perhaps the keynote of present day industrial progress

Twentieth Century Progress in Industrial Relations

By EDWARD S. COWDRICK
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THE years since the opening of the twentieth century, which have seen unprecedented advance in scientific production methods and in the application of mechanical power to industry, have also been characterized by profound changes in the relationships between employers and employees. Surface indications of this development are found in new methods and personnel practices, but more fundamental are the changes in philosophy and principles and in economic conditions which underlie the whole movement. To these deeper aspects of the subject we should turn our attention, if we wish to understand the significance of the various practices—employee representation, union-management co-operation, modern employment systems, stock distribution, pensions, insurance and the like—by which the progress of industrial relations has been marked.

Increased production of wealth and improved bargaining power of labor have brought a whole succession of changes in the economic status of the workers. They have played a dominant part in the bringing about of higher wages, shorter hours, the five-day week in some industries, vacations in numerous companies, and generally improved conditions of work.

With high wages has come a constantly rising standard of living—a standard which employers have no desire to lower, since in recent years the wage-earner has established himself as the best customer of the manufacturer and the merchant.

SECURE in his improved economic status, the worker has become in increasing measure a capitalist. American labor never has been strongly proletarian; it has become even less so in recent years of distributed prosperity and diffusion of industrial ownership.

The next step in the evolution of modern industrial relations practice, logically if not historically, is that of mutual adjustment of differences and co-operation in management. It is in this field that some of the most hopeful progress has been made—and fortunately so, since here must be solved those problems of justice and fair play, vital to any system of labor relationships.

The most significant development in this field has been the wide adoption in the last few years of the system of joint dealing known as employee representation. First attracting national attention no more than a dozen years ago, representation had a rapid (perhaps almost too rapid) growth during the World War and the two following years, suffered a moderate decline in the depression of 1920-22, and then began a gradual but steady growth which still continues.

Employee representation undertakes to set up machinery to replace the personal contacts between employer and workers which once prevailed in a small, owner-operated establishment. In its simplest and most rudimentary form, it is scarcely more than a method of exchanging information between company officials and committees of workmen. In more ambitious experiments, it may involve the sharing of management with labor.

SIMILAR in some points to employee representation, and in fact imitating some of its methods, is the system that lately has become prominent under the name of union-management co-operation. The principles behind this plan of joint dealing are simple. The employer "recognizes" and enters into contractual relations with the established unions in the trades in which some or all of his employees are engaged. With these unions he negotiates wages, hours and working rules. He allows them to be the spokesmen for his employees in adjusting grievances and handling mutual relationships. In return the unions undertake to foster efficiency and morale, to aid in enforcing discipline, and to co-operate with employers in improving methods of management.

Partly independent of the labor tendencies thus far discussed, but closely related to them and growing up at the same time, is a group of social safeguards against various hazards of the industrial worker. The adoption of workmen's compensation laws in nearly all states has thrown into the discard the ancient common law doctrines as to the financial responsibility for accidental injuries. Various types of life and disability insurance are growing in favor. Attempts of employers to solve the problem of old-age dependency have led to the wide adoption of industrial pensions and insured annuities. Realization of the losses due to unemployment—losses which fall not alone upon the jobless worker but upon his employer, upon industry in general and upon the community at large—has caused some experiments with unemployment insurance. A more significant result, however, has been the redoubled effort of enlightened managers to regularize employment through stability of operation and through increased care as to methods of building up and cutting down forces.

The scope of this summary permits only a mention of safety work, sanitation and medical care, recreation and education, and the whole list of service activities for the benefit of employees which have become matters of routine in most of the more advanced corporations. These activities, many of which have respectable ancestry in the once lauded "welfare work," have been somewhat overshadowed by the newer and more fundamental aspects of industrial relations, but they are still important.

Development of Lighting in Industry

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THE history of our earth, of life, of knowledge—of all things fluid—is measured in epochs or ages; and the length of these periods is inversely proportional to the rate of change. In the history of civilization the epochs have rapidly shortened as time passed, owing to accumulated knowledge and to the increasing intensity of interest in its application toward various ends. We may now look backward fifty years upon such great achievements industrially that this brief span is as much an epoch or age as any former period a hundred times longer.

The past half-century is worthy of various titles. Certainly it represents the entire span of the practical enslavement of electrical forces. Electric lighting was born just before this half-century dawned. The arc-lamp preceded the electric filament lamp. The first formal industrial installation of electric lighting was made in Paris in 1873, but in 1877 only a few factories were lighted by electricity in the entire world. In 1879 the carbon filament lamp appeared.

Fifty years ago a successful gas-mantle had not appeared. Meager gas-lighting by means of open flames was used when individuals were crowded with work. But there was little thought of operating factories after daylight failed. The work-day was generally bounded by sunrise and sunset. Even daylighting indoors was not adequately developed. The factory with large window-areas and special skylight construction is a modern product of the modern idea of efficient work under good conditions. But as natural lighting developed, artificial lighting progressed even more rapidly until, at the present time, they are generally comparable in cost. Furthermore, electric light is completely controllable in quality and distribution and is dependable every hour of the day or night; but daylight indoors is variable, is only partially controllable, is limited to certain hours, and may fail at any time.

THE COST of light today from tungsten filament lamps is only a small fraction of that of a half-century ago. If the unskilled laborer of fifty years ago had used as much light as is now used in the average home in this country, he would have had to work two and one-half hours each day to pay for his gas lighting in his home as compared with ten minutes per day now to pay his electric lighting bill. Industrial workers a half-century ago on a night shift would have had to work most of the time to pay for artificial lighting had it been supplied in the quantities now considered desirable. If the laborer of fifty years ago had used as much light in his home as he does electric light now and if he had used tallow candles, he would have been able to purchase nothing but light. This serves to illustrate that good lighting was economically impossible a half-century ago—and owing to the nature of the light-sources, it was actually unattainable. The enormous decrease in cost of artificial light has wrought a great change.

THE AVERAGE luminous efficiency of all tungsten filament lamps sold in this country at present is about ten times greater than that of the earliest practicable carbon filament lamps. Those used in industries are nearly fifteen times more efficient than the early carbon lamps. The average intensity of illumination in artificial lighting has steadily increased from practically zero fifty years ago to a few foot-candles at the present time. This increase has been due to the decrease in the cost of light although the former has not kept pace with the latter. A great impetus was given to artificial lighting in the industries when the tungsten filament lamp appeared in 1910 and a still greater one when the gas-filled lamp was developed in 1914. Just before the war a factory was considered well lighted if the intensity was three foot-candles. The feverish war-period of high production and mounting costs directed some attention to artificial lighting. Gradually the intensities in use increased until now we have many factories and workshops illuminated to ten foot-candles. Some more progressive ones are using as high as forty foot-candles.

MODERN artificial light turns night into day. We now have the possibility of a 24-hr. industrial day. We have long had it on railroads and elsewhere. A two-shift day is now in use in many factories and shops and obviously it aids materially in reducing costs of production by spreading the overhead over greater production.

Many tests have been made to determine the effect of illumination upon various phases of production. Almost always these have shown a considerable increase in safety to the workman, decreased spoilage, increased output, and a heightened morale. Experience indicates that the increased output in every work-place has more than paid for the entire artificial lighting bill. In some cases it has equaled several times the cost of lighting.

Modern electric lighting has come to be viewed by progressive industrial executives as a worker for the workers. With proper and adequate lighting the worker can see more quickly and more accurately with the same output of human energy than under poor lighting conditions. Thus good lighting is equivalent to a certain portion of the payroll. Whenever a worker can produce more with less output of energy and with greater comfort and safety, the worker as well as the employer is benefited.

Materials in the Metal Working Shops

NOTHING is more significant of the changes in the field of the *American Machinist* than the multiplication of the number of materials that go into the finished product. Fifty years ago machine tools operated on cast iron, wrought iron, steel and brass, for the most part and found them uncertain in structure.

Steel was either Bessemer, machinery or cast, as crucible steel was termed then. Bessemer was pretty poor stuff and machinery steel almost as bad. The cast steel was good enough to use for tools. Brass was yellow brass if it contained zinc; red brass if it contained tin. Speeds and feeds for cutting each of these materials were fairly well standardized and the machinist was expected to know them by instinct. Chemistry and metallurgy had hardly begun to make an impression on shop practice. In fact, they were regarded with considerable suspicion by men who still believed in the mystic efficiency of certain natural quenching mediums.

Today, cast iron is still cast iron but we have learned to vary the mix to adapt it to the requirements of the job. Wrought iron has dropped to a position of negligible importance. Steel is no longer steel but is now some one of scores or hundreds of carefully proportioned alloys, heat-treated for hardness or toughness or some other physical characteristic. Brass, likewise, has special compositions for special requirements and has been joined by many more non-ferrous alloys, from tobin bronze to duralumin.

THE machining of the alloys employed today—practically every metallic material that comes into the shop now is an alloy—is only possible because of the drastic changes in machine tools, in cutting tools and in methods since 1877. Carbon steel tools are helpless before some of the harder alloy steels of which certain machine parts are now made, and even stellite must give way to the abrasive wheel before others can be formed. There is this much in our favor today, however. The materials that are supplied to us now are uniform in quality. That much, at least, has been secured through the system of purchasing to material specifications worked out by government departments, big corporations and such engineering bodies as the A.S.M.E., S.A.E. and A.S.S.T. Thus it is feasible to spend some time and effort in determining the best means of machining a refractory material, because, once determined, we can continue to apply it on future lots of the material.

It is true, of course, that even today variations in quality will occur but they are so much less frequent and so much smaller than those that plagued the machinist fifty years ago that they are relatively insignificant.

It would be out of the question here to attempt to enumerate all of the alloys that now must be machined, formed, ground or heat treated in the metal working plant. Some are valuable for their combination of lightness and strength; some for their ability to resist heat; some for their ability to resist abrasion; some for their resistance to acids or other chemicals. Most of them contract on cooling but there are others that expand and a few that remain constant in size. Some can be welded; others cannot. It is possible to form some materials under the press or hammer or in the forging machine; but not others. Some must be machined dry, others wet; some at high speeds, others very slowly. All of this means simply that almost infinite complications have been introduced into the art of metal working and that scientific methods must be employed if satisfactory results are to be secured.

NEW methods of fabrication are also affecting the materials used in the shop. Welding, for example, is increasing the amount of pressed and rolled steel and lessening the amount of cast iron entering into the finished product.

But, in addition to all of the new alloys that must be worked by the man in the shop, there is a host of non-metallic substances that form some part of the finished product and are usually finished by machine tools. Vulcanized wood fiber, resins, casein, glass, porcelain, graphite, carbon, hard and soft rubber are easy enough to handle if you know how and have the proper equipment. But the machine speeds that are right for alloy steel may be quite wrong for a gear made of fabric and resin vulcanized. Likewise, the rake and clearance angles needed to cut one material may be quite at variance with those required for another.

The materials that have become available during the last fifty years have opened a whole new field to the designer. He can now select just the material he wants to make his design balance in every detail. He is no longer hampered by the fact that the only material of which a given part could be made was so weak that the part had to be made disproportionately large in order to stand up.

With the new materials have come, of necessity, various kinds of physical and chemical tests to insure that they meet specifications. Tensile tests, impact tests, fatigue tests, hardness tests, wear tests and various special tests have been devised to make sure that materials were really what they pretended to be. But as yet no one has been able to devise a thoroughly satisfactorily "machinability" test—perhaps because there is no puncture-proof definition of machinability. When that comes the metal working industry will be ready for another big forward step.

Advances in the Practice of Handling Materials

MATERIAL handling has a big share in making possible greater economies in machine production. Few phases of modern production have so wide a scope, as material handling includes everything from the tote-box and wheel barrow to the most elaborate conveyor system or the largest crane. It begins with the receipt of rough stock, carries it to stores, to the machines, to assembly; moves the assembled units or product; and finally delivers the finished articles to the shipping platform.

Boxes, barrels, and bins have been used to store or transport material for many years. Beginning with little or no attempt at system, tote boxes were soon standardized for stocking or storing. Bins and platforms were arranged to be transferred from one department to another by hand-operated trucks or to be carried by traveling cranes to other parts of the plant. Now, lift trucks, hand or motorized, have become a part of standard equipment in every plant and their movements are controlled by dispatchers to secure the greatest amount of effective service from each truck.

Jib cranes, both of the post and wall type, were used many years ago. They still supplement the traveling crane. But they have changed from the crude, wooden affairs with rope and windless, or chain block, to steel construction with power hoists. Compressed air and electricity are rivals as power sources, the former being used either in the straight lift cylinder or in a small air motor working through suitable gearing.

TRAVELING cranes have come through several stages. These include the old square shaft drive, compressed air motors with long loops of air hose, and now the electrically driven crane with separate motors for the different functions. The economical uses of traveling cranes proved something of a study, as the tendency was to use them in cases where other means of handling were cheaper, especially when used as auxiliaries to the larger cranes. There is a story of a big crane being used to pick up a handsaw and carry it the length of the shop. The modern traveling crane is indispensable in most modern plants where heavy weights are to be handled. Auxiliary hoisting drums have widened its field by reducing hoisting costs on lighter loads.

In multi-story buildings the elevator becomes a part of the conveying system and too frequently adds to the cost by reason of the handling that becomes necessary in loading and unloading and the time taken by the movement. The use of lift trucks to deposit the load on the elevator is one method of saving time. In other places the elevator carries a lift truck so that the elevator operator can unload the platform or bin at the proper floor. With a really busy elevator, however, this might be more loss than gain. A more efficient method in most cases is to have the elevator platform large enough for a motorized lift truck to run on to it and be hoisted or lowered to the proper floor. There it runs off and delivers its material with no further handling.

Conveyors are supplementing the elevator in plants where the volume and character of the work warrant. The term "conveyor" covers a multitude of appliances, from the inclined slide, or the frame of rollers, to elaborate combinations of belts, hoists and runways that go in any direction and frequently deliver the work automatically at pre-determined stations. Conveyors perform two functions, they save the manual exertion of lifting and carrying and they also reduce the number of men necessary to keep material moving through the plant.

A NUMBER of the plants making small parts have installed special types of conveyors consisting of a belt or some form of chains or receptacles into which parts are placed. These conveyors carry the work in any direction, horizontally, vertically or at any necessary angle. They go through partitions and floors, around corners, and in some cases travel on the outside of a building until they reach the desired point and go inside to the assembly line or to stores. For open work that can be hung up, hooks are attached to overhead chains and the work carried to the next workman or to another department.

Among the other types of conveyors used is the monorail which, suspended from the ceiling, carries material to any point, around curves, in doors or out. A small cage carries the operator below the rail. Tractors, electric or gasoline, are also used to pull small carloads of material, frequently in trains of six or more cars. They have supplanted the so-called industrial or narrow-gage railways that formerly ran from one plant or department to another.

When used to time operations, as where articles are assembled on a constantly moving conveyor, the conveyor method has a "leveling" effect. It speeds up the slower operators to a higher output than can be secured without it. On the other hand it slows the very rapid operator to a pace that can be maintained by the average. "Keep it three feet above the floor—and moving," is the slogan of one big manufacturing plant and is representative of the times. More waste occurs in handling materials or parts than in performing operations on them, and therefore management is now paying close attention to the elimination of this type of waste and will continue to do so.

Taps, Dies and Related Tools in the Machine Shops

AMONG the small tools of the machine industry few have been the subject of more controversy than those used to cut threads upon bolts, screws, and other parts, and in holes too small to be threaded in a lathe. Prior to the middle of the last century they were rarely to be obtained on the market, and the mechanic who had use for them was obliged to make them for himself.

Blacksmiths made taps upon the anvil, using a hot-chisel and hardy to make a more or less regular helical groove of V-shape around the blank to represent the thread and cutting the rudimentary flutes by the same means, afterward smoothing up the product with a file. Having the taps, they could make corresponding dies by drilling a hole in a blank and threading it with a tap.

The mechanic to whom the thread-cutting lathe was available could do a better job of threading, and, if he chose, could make quite serviceable tools. If he had a milling machine he could do an equally good job of fluting; otherwise he would be content to file three or four flats on the threaded blank and call the result a tap.

A man who learned his trade in the '50s once told the writer that his first job was to assist in tapping the hubs of some large pulleys for setscrews, using this kind of a tap. "The job," he said, "was one for two men and a boy." The taps, having a negative rake, could do little more than jam a thread in the hole, and the efforts of two husky men were required at the wrench to turn it. It was the boy's job to keep oil on the tap. Sometimes a hub would be split by this method of tapping.

Dies were equally crude, and were generally of the one-piece type; threaded with the tap, and with cutting edges provided by drilling clearance holes to intersect the threads. As cutting tools they were superior to the taps, for the clearance holes could be so disposed as to provide plenty of rake. It was customary to make several dies of different sizes in one plate having forged handles at the ends; hence the name "die-plate."

AN improvement (?) upon this type of tool was the "jam-plate," without which no self-respecting machinist considered his tool kit complete. It consisted of a rectangular frame, with one of the handles forged integral, in which could be placed several dies, each made in two pieces but in much the same way as the "solid" die. The other handle screwed into the end of the frame opposite to the permanent one and provided means to adjust the dies. Any number of dies could be made to fit the frame, and, because of the adjustment, each die would take care of a limited range of diameters; a very desirable feature in the days when a given diameter meant anything within $\frac{1}{32}$ in. above or below the nominal size.

When and by whom taps and dies were first made commercially we do not know, but James M. Carpenter, himself early identified with the business, long ago told to a member of the *American Machinist* staff the story of Benjamin Bee, who, in 1866, started to manufacture them in a little shop down on Cape Cod. The story is too long to be printed here, but it may be found on page 995, Vol. 30 (Dec. 26, 1907) of this journal.

Bee contributed much toward making the tap a real cutting tool, and many of his ideas are incorporated in modern tap-making machinery. During the following years Bee seems to have had more than his share of trouble, for his shop burned down, his backers went back on him, and, finally, what was left of his business was re-established under the name of The New York Tap & Die Co., in Essex, Connecticut.

Of this business E. A. Goddard was in charge, and he, too, added more to the mechanical than to the business side of the venture. He devised several machines to increase production, the principles of which are still used. He also brought out a hand reamer with left-hand helical flutes, but whether or not he was the first to do this we do not know.

IN 1871 John J. Grant invented the two-piece adjustable die, known as the "Lightning" die, which is said to be the first tool of its kind actually to *cut* a thread; the older dies being rather of the order of the jam-plate.

Forming a co-partnership with Solon Wiley and John Russell of Greenfield, Mass., Grant started in 1872 to make taps and dies for the market. His company, later the Wiley & Russell Manufacturing Co., bought out Goddard's business in Essex and brought the machinery to Greenfield, where it was perfected. This and other companies, many of which were started by men who had been in Wiley & Russell's employ, have helped to make the name of Greenfield prominent in the tap and die industry.

James M. Carpenter, above mentioned, was never connected with the Greenfield interests. He learned the machinist's trade at Brown & Sharpe's and in 1873 started making taps in Pawtucket, R. I. Another name that is quite prominently identified with the business is that of Simon W. Card, of Mansfield, Mass., who started in the same line and about the same time as Mr. Carpenter. Nearly all of the tap and die shops in New England have grown out of one or other of these three pioneer concerns.

Methods employed fifty years ago to make taps and dies would now be considered rather crude and the

standards then followed uncertain. Though the standards of Whitworth in England and the U.S.F. in America had been established, standards of any kind were much easier to talk about than to observe. The sharp V-thread of 60-deg. angle was easier to make than the 55-deg. rounded profile of Whitworth, met the then existing conditions satisfactorily, and for years remained the basic thread of America.

Tap blanks were turned on engine lathes and sized to spring calipers set to individually-owned steel rules that might or might not have been all alike—and probably were not. Threads were cut sharp on the sized blanks, and when the job *looked* right it *was* right, beyond dispute. Pitch diameters were ignored.

The angle and uniformity of lead of a tap were as nearly correct as were those of the leadscrew of the lathe that generated the thread—before hardening. After hardening? Well! How was anybody going to know what would happen to a piece of steel in the fire and quenching tub?

NOTWITHSTANDING the apparent latitude in the making, the taps and dies produced were very good tools indeed for the days when "half-a-sixty-fourth" was a mighty close measurement. Improvements of later days have been apparent chiefly in closer adherence to sizes and thread forms. Longer life at higher speeds is due principally to better and more uniform steels, to high-speed steels, and to scientific methods of heat-treatment.

Ground threads are no new thing, but the process used to be considered too costly for a production measure and it was not until recent years that the demand became insistent enough to force its adoption. When forced to it the manufacturers found that ground threads could be produced at little or no greater cost than by older methods. Some manufacturers even flute the blank and *harden* it before generating the thread.

The self-opening die has contributed no little toward the present-day accuracy of screw threads. A tap can produce only internal threads, while the die is the principal means of making external threads. The increasing accuracy of the tap is reflected in the die, as the tap is usually the means of making the threads in the the latter. This is not always the case, as there are some types of self-opening dies in which the chasers have their threads generated by grinding.

The self-opening die-head finds its principal field in connection with the screw machine, in which it is of special advantage because of its feature of withdrawing the chasers radially from the work when a sufficient length of thread has been cut, there being no need to reverse the direction of rotation or even to stop the spindles. As the die does not have to be run off the thread there is no spoilage from dragging and stripping.

Corresponding to the self-opening die is the collapsible tap the threaded portion of which is made up of several movable chasers supported by a sliding wedge that may be withdrawn to allow them to recede from the work. It possesses the same advantages as the die-head, but because of the necessity for confining all of the mechanism within the compass of the hole it cannot successfully be applied to very small sizes.

Another old tool that has come into extended use during the past few years is the self-reversing tapping head, also applied to external threading by substituting a die for the tap. This tool has its principal application in screw machines, though large numbers are used—especially in the automobile shops—in multiple-head drilling, or machines of similar type.

For tapping nuts and similar symmetrical parts a machine has been developed which does away with the need for reversing the spindle or for removing the long-shanked taps periodically to take off the accumulated nuts. It employs a tap with a shank that is bent in a long-radius curve to a right angle with the threaded portion and supported in the machine by the work in such manner that blanks may be fed to it continuously; a threaded nut dropping off the end of the bent shank each time a blank comes on the other end.

External threads are produced by a process of rolling the blank between flat dies upon the surfaces of which is cut a series of grooves having the form of the thread and disposed at an angle to correspond to the helix angle of the desired screw. The metal is not cut by this process, but is forced by the pressure to assume the shape of the grooves in the die.

Measuring appliances, themselves the subject of marked improvement during fifty years, have served their purpose to better advantage in no other branch of the industry than in enhancing the accuracy of screw threads. Precision measuring machines serve to check errors of lead; thread micrometers measure screws by their pitch diameters; optical comparators challenge the accuracy of thread forms against the background of a greatly magnified chart that discloses errors of 0.0001 in. more readily than a variation of $\frac{1}{64}$ in. could be discerned in the earlier days.

Conversely, the improved screw thread has made possible the accuracy of the sensitive measuring instrument. When taps and dies first appeared there were no micromters to measure them and sizes could not be depended upon. When micrometers were first made there were no screws good enough to constitute the basic principle of the tool, and threads must be improved to meet the new condition.

FOR many years the threaded ring gage was practically the only means of testing and inspecting screw threads. It is but recently we have discovered that a thread too large in some of its characteristics may pass the gage while one that is too small in other respects may not go through. All this has been corrected by modern systems of gaging, and we are now measuring threads in split-thousandths more easily than we formerly gaged them in hundredths.

We now have a standard of tolerance worked out by the National Screw Thread Commission that has done much to assure interchangeability in threaded work. These standards have resulted in substantial savings in the production of bolts, screws and nuts and will still further add to economy as time goes on.

Ample excuse for past variations in screw threads that ought all to have been of one nominal size, as well as urgent reason for reducing these variations and standardizing the product may be found in the statement of a prominent manufacturer of screw thread cutting tools to the effect that there are cut in the United States *two hundred million* screws *every day*.